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CONTENTS

Decay of various vegetables and fruits by different species of Rhizopus ..... L. L. HARTER AND J. L. WEIMER 225

Root rot of pine seedlings ..... ANNA E. RESSEGUIE .. 233

Viability of hulls of Cronartium ribicola in early winter .. PERLEY SPAULDING 238

Insects as disseminators of plant diseases:
I. Results of past investigations ..... FREDERICK L. KNOX 239
II. Systematic relations of carriers ..... E. M. HALL 260
III. General problems ..... L. CRANDALL 281
IV. Urgent problems of the future ..... MAX W. GARDNER 283

The cooperative potato spraying project: Report for 1921 ..... G. H. BOOSE, H. E. CRAWFORD, W. H. MARTIN, J. T. ROSA, JR., E. A. STOREY 241

Report of the fourth annual meeting of the Southern Division of the American Phytopathological Society, Atlanta, Georgia, Feb. 20–22, in connection with the annual meeting of the Association of Southern Agricultural Workers 249

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PHYTOPATHOLOGY

VOLUME XII NUMBER 5

MAY, 1922

DECAY OF VARIOUS VEGETABLES AND FRUITS BY DIFFERENT SPECIES OF RHIZOPUS

L. L. HARTER and J. L. WEIMER

Observations have shown that Rhizopus is commonly associated with decayed fruits and vegetables of many kinds. Stevens and Wilcox (11) found that *Rhizopus nigricans* Ehrnb. causes a rapid deterioration of strawberries in transit, and Harter, Weimer, and Lauritzen (9) found that nine different species of the genus will decay sweet potatoes. Behrens (1, p. 515–516) showed that tomatoes were readily decayed by *R. nigricans*. The common occurrence of Rhizopus on fruits and vegetables has been repeatedly observed, especially on such crops as potato (*Solanum tuberosum* L.) (10), quince (*Cydonia vulgaris* Pers.) (4), pear (*Pyrus*), raspberry (*Rubus*), currants (*Ribes*), plums (*Prunus*) (1, p. 515–516), figs (*Ficus*) (2), red raspberry (*Rubus strigosus* Michx.) (11), fruits of *Cornus mascula* L., *Moris alba* L., and apple (*Pyrus malus* L.) (3). It has been observed by inspectors of the Bureau of Markets of the United States Department of Agriculture to occur on bean (*Phaseolus vulgaris* L.), beet (*Beta vulgaris* L.), cabbage (*Brassica oleracea* L.), onion (*Allium cepa* L.), squash (*Cucurbita pepo* L.), pepper (*Capsicum annuum* L.). egg plant (*Solanum melongena* L.), and other vegetables.

A review of the literature dealing with the decay of vegetables and fruits by Rhizopus shows that, although several crops have been mentioned as hosts, only a relatively small number of inoculation experiments have been conducted to determine its parasitism. Futhermore most of the losses due to this group of fungi have been attributed to a single species, *R. nigricans*. In view of the fact that nine species are able to decay sweet potatoes, it was decided to test the parasitism of these together with two other species nonparasitic to sweet potatoes on a number of the common vegetables and fruits. The necessity for such investigations is all the more apparent when it is recalled that

Hanzawa (5) found that the species of Rhizopus differ considerably in their temperature requirements. He found that they could be roughly separated into three groups with respect to temperature—high-, intermediate-, and low-temperature forms. Moreover, it has been demonstrated (9) that the low-temperature forms would not infect at high temperatures nor the high temperature forms at low temperatures, or at least only with difficulty. *R. nigricans*, one of the low-temperature forms, has practically always been cited as the species responsible for the decay of the different hosts. However, there are certain crops which are handled at relatively high temperatures, and it is probable that other species than *R. nigricans* may produce decay under these conditions.

METHODS OF EXPERIMENTATION

Two methods of inoculation were employed. If the crop was one which was more or less succulent or appeared to have a high water content, such as cauliflower, the inoculations were made by the insertion of spores and mycelium into a wound made with a needle. If, on the other hand, the crop was one which was relatively low in water content, such as dasheens, the spores were germinated and grown for one or two days in sweet potato decoction, which was then poured into a "well" made according to a method already described (8). The reasons for employing this method have been discussed in a previous paper and will therefore not be considered further here. In all cases enough material for an entire experiment was obtained at one time and from the same sample. In general all the products were treated alike. They were thoroughly washed and cleaned, and the experiments were carried out under as nearly aseptic conditions as possible, although in no case could absolutely sterile conditions be assured. Some of the vegetables and fruits were put into covered moist chambers and incubated at the temperature best suited for the growth of the fungus with which they were inoculated. Other crops, such as strawberries and raspberries, were placed in Erlenmeyer flasks and then inoculated by pouring a suspension of spores in water upon them.

Three temperatures were employed, 20° to 22° C; 30° C, and 35° C. These temperatures were selected because it was found that the different species of Rhizopus could be roughly separated into three groups with approximately these optimums.

The duration of the experiment depended upon the host and the rapidity of decay. In most cases it continued for from three to five days. Usually it was not continued long enough to permit of complete decay of the host, but merely long enough to determine whether or not the particular crop was susceptible to decay by the different species.

As soon as the susceptibility of the host was evident, the causal organism was isolated from each individual inoculated, with the exception of such fruits as strawberries, raspberries, blackberries, etc., and identified. If the experiment was not permitted to continue too long so that the decayed tissue was overrun with saprophytic bacteria and fungi, a pure culture could usually be obtained.

EXPERIMENTAL DATA

The parasitism of species of Rhizopus has been tried on 27 different hosts, as shown by table 1. The number of individuals inoculated with each species of the genus was usually small (4 in the case of such hosts as cantaloupes, squash, turnips, etc.). The total number inoculated with all the species and the results of all the inoculations gave in most cases quite conclusive evidence as to whether or not a certain host is susceptible of decay. If in any case there was any doubt, the inoculations were repeated until reasonably conclusive proof of the susceptibility or resistance of the host to the particular species under consideration was obtained. Controls were carried for all the experiments. One set of controls was held at 30° C and another at from 20° to 22° C. If in any case the controls were decayed, the causal organism was isolated and identified. The duration of the experiments was only from three to five days, the controls usually remaining sound for that length of time. The controls which decayed were mostly of such hosts as strawberries, raspberries, and blackberries, which, although they were carefully handled when washed and prepared for the experiments, were more or less mutilated.

In all cases an attempt was made to inoculate the host by the insertion of spores and hyphae into a wound made by a needle. However, in order to obtain infection of some hosts (Irish potatoes, dasheens, beets) it was necessary to employ the "well" method.

The figures shown in the table give the percentage of hosts infected in each case and not the amount of decay at the end of the experiment. As a matter of fact, the total amount of decay at the close of the experiment varied greatly, even among species which were marked 100. Infection was considered to have taken place when the tissue about the point of inoculation was softened beyond that which resulted from artificial wounding of the controls. Care was taken not to overestimate the percentage of infection by certain organisms (*Rhizopus chinensis*, *R. microsporus*), which in comparison with other species produced a relatively small amount of decay.

The sweet potato, the host which probably suffers greater loss from decay by Rhizopus than any other crop, is not included, since an extensive study was previously made of its susceptibility to decay by the different species of Rhizopus, the results of which have been published elsewhere (9, 7).

DISCUSSION OF RESULTS

The results recorded in table 1 show that a number of the fruits and vegetables are susceptible to decay by the different species of Rhizopus.

TABLE 1.

Percentage of infection by species of Rhizopus on various hosts

Hosts	Incubation temperatures										
	35°	30°							20°–22°		
	Chinensis	oryzae	maydis	tritici	delemar	nodosus	arrhizus	artocarpi	reflexus	microsporus	nigricans
Grapefruit	100	100	100	100	100	100	...	100	100	00	100
Orange	100	100	100	100	100	100	...	100	100	75	100
Lemon	50	100	100	100	50	100	...	75	100	100	100
Turnip	75	100	100	100	100	100	...	75	100	00	25
Parsnip	100	100	100	100	100	100	...	100	100	00	100
Rutabaga	100	100	100	100	100	100	...	100	50	00	75
Carrot	50	100	100	100	100	100	100	50	100	00	25
Pepper (green)	100	100	100	100	100	100	100	100	100	100	100
Cucumber	50	100	100	100	100	100	100	100	100	00	75
Potato	40	100	90	100	100	100	90	90	90	00	65
Apple	00	100	100	100	100	100	100	100	100	00	100
Dasheen	50	100	100	100	100	100	75	100	75	00	100
Peas	00	100	100	100	100	100	100	00	00	00	00
Bean	100	100	100	100	100	100	100	50	50	00	100
Beets	00	75	25	25	50	50	50	00	00	00	00
Yam (Dioscorea)	...	...	...	90	...	...	...	...	...	...	90
Strawberries*											
Squash	00	100	100	100	100	100	100	100	100	50	100
Blackberry*											
Raspberry (red)*											
Cauliflower	00	...	...	100	...	...	...	...	...	00	100
Peach	100	100	100	100	100	100	100	100	100	00	100
Cantaloupe	100	100	100	100	100	100	100	50	100	50	100
Watermelon	00	100	00	100	100	100	50	100	100	00	100
Eggplant	00	100	100	100	100	00	100	100	00	00	50
Plum	...	...	...	...	...	...	...	...	...	...	...
Pear	100	100	100	100	100	100	100	100	100	50	100

* Decay readily. Impossible to obtain reliable results with different species.

Some hosts are decayed with more difficulty than others, for instance beets. On the other hand, there are some which succumb readily to all the species. At the outset of these experiments the writers were not in possession of a culture of *Rhizopus arrhizus*, therefore no results were obtained for a few of the hosts with this species. The species

microsporus and *chinesnis* are for the most part nonparasitic, and it is doubtful whether either of them will be very often found on decaying fruits and vegetables on the markets. However, under the conditions of these experiments, in which they were removed from the competition of other fungi, they produced decay of certain hosts.

The different species have been arranged in three groups, according to what seemed to be the optimum temperature for infection—i. e., high-, intermediate-, and low-temperature forms. *Rhizopus chinensis* is the only representative of the high-temperature group. The optimum temperature for the growth of this species is distinctly higher than that of any of the other species. In the intermediate groups are *oryzae*, *maydis*, *tritici*, *delemar*, *nodosus*, and *arrhizus*, whose optimum temperature was found to be about 30° C. The low-temperature group is represented by *artocarpi*, *reflexus*, *microsporus*, and *nigricans*, whose optimum is about 20°–22° C. *R. chinensis* is weakly parasitic on a few hosts. If, however, an examination is made of the results obtained with the intermediate-temperature forms it will be seen that they are all vigorous parasites. As a matter of fact, these species produced a higher percentage of infection and a more rapid decay than the species of the other groups. However, so far as the writer's experience goes, none of the species in the intermediate group are met with as frequently in nature as *nigricans*, which seems to be the immediate cause of most of the decay produced by this group of fungi. It is exceedingly surprising that species which under laboratory conditions are such vigorous parasites are so seldom found on decayed fruits and vegetables in storage or on the markets. *Nigricans*, the species most often isolated, produced a smaller percentage of infection than either *artocarpi* or *reflexus*, two species only occasionally isolated from decayed material.

The hosts differed considerably in the ease with which infection took place and the method necessary to accomplish it. Some hosts, such as beets and potatoes, could be infected only after the spores had been germinated in a nutrient solution and had grown on the medium for from 24 to 48 hours, while other hosts (cantaloupes, cucumbers, oranges) can readily be infected by merely inserting spores and hyphae into a wound made by a needle. The method of inoculation required seems to depend upon whether or not the host is juicy or relatively dry. On Irish potatoes and beets it seems that it is necessary for the enzym pectinase to be secreted in sufficient quantity to macerate the tissue in advance of the growing hyphae, as the writers have shown to occur in infected sweet potatoes (6). However, on hosts with a higher water content, the organism seems to be able to infect when the spores and mycelium are inserted directly into the tissue. The different species

vary in their ability to infect certain hosts by merely inserting spores and hyphae into wounds. For example, *tritici* infected apples readily when spores and hyphae were inserted into them, while *nigricans* did not, although the latter species did infect when the "well" method was employed. The dasheen was likewise more readily infected by the prick method with *tritici* than with *nigricans*.

The data obtained from the inoculations of strawberries, raspberries, and blackberries are not entirely satisfactory. There is no reason to doubt but that these three hosts are decayed readily by Rhizopus, but to prove that each of the species of Rhizopus will decay them has been surrounded by many difficulties. In the first place, the controls decayed readily, showing the presence of Rhizopus. In some few cases the writers isolated the species with which the inoculations were made in pure culture. More often, however, either *nigricans* or *tritici* or a mixture of two or more species was isolated. It was possible in some cases to recover the species with which the inoculation was made mixed with either *nigricans* or *tritici* or with both. The results with these three hosts proved their susceptibility to decay, but they can hardly be interpreted as showing the parasitism of all the species.

Rhizopus seems to be characterized by its inability to infect except through wounds. Of all the different hosts tried, only one, the peach, seemed to be infected without any apparent wound. It is of course difficult to say with certainty that there was no wound through which the germ tube entered, but the evidence seems to indicate that infection can take place through the unwounded surface. What appeared to be healthy, ripe peaches were dipped in a spore suspension of *nigricans* and of *tritici* and infection resulted. Rhizopus seems to be further characterized by its inability to grow outward through the unbroken skin. On the other hand, if the skin or epidermis of an infected host is broken, the hyphae grow through the wound and sporangiophores are formed abundantly on the surface. Here again peaches constitute an exception. It was found that the sporangiophores grew outward through the skin at all points on the surface and fruited abundantly.

The writers' results with peaches and to some extent with plums indicated that the decay generally regarded as brownrot may be caused in part at least by Rhizopus. Isolations were made from 139 partially decayed peaches collected on the retail markets of Washington. Two plates remained sterile, while *Sclerotinia cinerea* (Bon.) Schroet. was obtained from 76, Rhizopus from 44, bacteria from 5, and *S. cinerea* and Rhizopus from 12, showing that the two organisms may be jointly responsible for the rotting of peaches. *Nigricans* was the predominating species. The species obtained from one or two of the isolations belonged to the *tritici* group and three resembled *artocarpi* but differed from the

latter species in some important details. The appearance of the decay caused by *S. cinerea* and Rhizopus is so much alike that it is readily understood how one might suspect one organism and entirely overlook the other. In the early stages of decay there are no outstanding differences which would enable one to separate the two. When the decay becomes more advanced, the skin of peaches decayed by the brown rot fungus turns slightly darker, while that of peaches decayed by Rhizopus remains brown. In the last stage of decay the fruiting on the surface is so different and characteristic as to be unmistakable. Under the conditions of the writers' experiments with the two organisms Rhizopus produced the more rapid decay.

Isolations were made from 66 plums collected from the retail markets of Washington and Rhizopus was obtained from 27, *Sclerotinia cinerea* from 34, and 5 plates remained sterile.

These results show that Rhizopus is prevalent on decayed peaches and plums on the markets. It has also been frequently isolated from other fruits and vegetables. Squashes are especially subject to decay by Rhizopus, while watermelons, cucumbers, cantaloupes, etc., have been often collected in the retail markets more or less completely decayed by this fungus. *R. nigricans* is the predominant species isolated, though species of the *tritici* group are occasionally met with. The results of these experiments, together with the fact that Rhizopus has been observed so frequently on and isolated from decayed material in storage or on the markets, show that this organism is one of the most destructive and prevalent of the rot-producing fungi.

SUMMARY

(1). A study was made of 11 species of Rhizopus on 27 different hosts. All the hosts were susceptible to decay by some of the species. Two species, *microsporus* and *chinensis*, were more or less nonparasitic —i. e., they infected only a few of the hosts and in those cases somewhat weakly.

(2). The species of the intermediate-temperature group are, on the whole, more vigorous parasites under artificial conditions than the members of the low-temperature group. Observations and investigations thus far seem to indicate that *nigricans* is the predominating species causing decay of fruits and vegetables in storage and on the markets. This species was obtained in most cases from decaying material collected from the markets. Occasionally one of the species of the intermediate-temperature group was isolated.

(3). The method of inoculation necessary to produce infection depended upon the host; beets, Irish potatoes, and those crops apparently low in water content could be infected only by the "well" method. Others, on the other hand, that were watery or juicy could be infected by merely inserting the spores and hyphae into a wound made by a needle.

(4). None of the hosts could be infected without wounding, with the possible exception of ripe peaches. Peaches with no apparent wounds when dipped into a spore suspension became infected, and sporangiophores were formed on the surface. A considerable percentage of the peaches and plums on the retail markets decayed with what appeared to be the brownrot organism were found to have been decayed by Rhizopus.

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ROOT ROT OF PINE SEEDLINGS

ANNIE E. RATHBUN

WITH ONE FIGURE IN THE TEXT

For several years coniferous seedlings too old to succumb to the more ordinary types of damping-off—namely germination loss, normal damping-off and top damping—recognized by Hartley (4) have been known to suffer from late damping-off and root sickness or rot. Büttner (1) studied the root rot of coniferous seedlings and while he apparently made no isolations or inoculations, held *Fusoma parasiticum* responsible for at least part of the rot. Gifford (2) isolated a species of Fusarium from the roots of 2 year old seedlings of *Pinus strobus* L. and 1 year old seedlings of *P. sylvestris* L. Although he apparently performed no inoculation experiments he not only thought that this species of Fusarium was capable of causing damping-off and root rot but also expressed the opinion that it may sometimes even kill the older seedlings by attacking the roots and stems. Hartley (3) stated that a "*Rhizoctonia* species (probably *Corticium vagum* B. and C.) which causes damping-off of very young seedlings, sometimes continues to work in patches till the seedlings are 2 months old or even more." Therefore in order to establish experimentally what these field observations seemed to indicate, namely that damping-off fungi may be responsible for these root injuries, 4 experiments were carried on with pine seedlings. The results of an earlier experiment of this sort have been reported by Hartley (4). Most of the fungous strains used in the experiments described below have been tested as damping-off parasites by Hartley and his associates, (4), (5). Results with the same strains in damping-off inoculations by other methods will later be published by the writer.

The seedlings for all 4 experiments were grown in the greenhouse in autoclaved sand until the time of inoculation. They, however, had been watered for several months with unboiled water. At the time of inoculation, the seedlings were carefully dug up and the root systems washed with boiled water. In the first 3 experiments (numbers 112, 113, 114) a little autoclaved sand was placed in the bottom of 4 inch pots and on top of it in each pot were placed 10 apparently healthy seedlings. Next inoculum which for each pot consisted of fragments of the mush made from one-third teaspoonful of rice plus the mycelium and any spores growing upon it, was laid against a portion of the root

systems of the seedlings. The inoculum was taken from cultures approximately 1 week old, but the strains themselves had been isolated several years. An equal amount of sterile rice mush cut into fragments was added to each control pot. Inoculum and roots were then covered with autoclaved sand. Unboiled water was still used to water the seedlings. In experiment number 112 two units of 10 six months old seedlings of *Pinus resinosa* Ait. were inoculated with each fungus. Experiment number 113 was a duplicate of number 112 except that about 2.5 inches were cut from the root system of each seedling before inoculation, in order to ascertain whether wounding would increase the susceptibility of the seedlings, and that but one unit of 10 seedlings was inoculated with each fungus. In experiment number 114 four-months old *Pinus banksiana* Lamb. seedlings were substituted for those of *P. resinosa*. The data were taken at the end of 40 days, the roots of the living seedlings being carefully washed out to permit examination. In experiment number 119, 10 seedlings of *P. resinosa* were placed in Erlenmeyer flasks in which fungi were growing on rice mush. The whole root system was in contact with the inoculum. The counts were made at the end of 10 days and are hence less reliable than those for the other 3 experiments because they do not show the full effect of the fungi.

The fungi tested were *Pythium debaryanum* Hesse, *Corticium vagum* B. and C., *Fusarium spp.*, *Botrytis spp.*, *Phomopsis juniperovora* Hahn and *Rheosporangium aphanidermatus* Edson.

RESULTS

The results of these experiments are given in figure 1 and table 1. Unfortunately they are based upon the inoculation of too few seedlings to admit discussion of the comparative virulence of the different strains, but they do permit to a certain extent at least a comparison of the different genera. A small amount of root rot developed in the controls and a similar amount in some of the inoculated pots. However *Corticium vagum* caused a decided increase in the amount of root rot while *Pythium debaryanum* and the cinerea type of Botrytis, caused more or less decay to most of the roots. Strains of *Fusarium spp.* gave variable results, but as a whole in the pots inoculated with Fusaria root rot was more serious than in the average control. A more detailed discussion of the results with the various genera based upon a direct comparison of the number of seedlings with undecayed roots remaining after inoculation (Fig. 1) is given below.

Pythium debaryanum. In experiment number 112, each *P. debaryanum* strain caused more decay than was present in the two controls with the least number of undecayed roots. In the average control for number 112, there remained at the end of the experiment five times as many

seedlings with undecayed roots as in the average *P. debaryanum* pot; in that of number 113 there were about twice as many; in that of number 114, there were about eight times as many, while in that of number 119 there were about five times as many. Several of the *P. debaryanum* strains caused browning of the tops as well as decay of the root systems.

FIG. 1. Diagram showing effect of fungi on the root systems of conifers. Black = number of seedlings with root system wholly decayed. Stippling = number of seedlings with root system partially decayed. White = number of seedlings with roots undecayed or only doubtfully decayed. Each rectangle represents one unit of 10 seedlings in experiments numbers 113, 114, 119, and the average of two units of 10 seedlings each in experiment number 112.

This latter is the late damping-off described and illustrated by Hartley (5). These experiments not only confirm Hartley's (4) report that *P. debaryanum* can cause root rot of one and a half months old *Pinus resinosa* seedlings, but show that it can attack 6 months old ones as well (Tab. 2).

Corticium vagum. In experiment number 112, the number of seedlings with undecayed roots in the average control was slightly greater than in the average *Corticium vagum* pot; in number 113 the numbers were approximately equal; in number 114, there were more than 10 times as many seedlings with undecayed roots in the average control; while in number 119, there were about twice as many. No late damping-off was observed. Although strains number 147 and 213, caused less rot

TABLE I

Summarized Results of the Experiments

Inoculating fungus	Experiment number	Number of seedlings inoculated	Percentage with wholly decayed root system	Percentage with partially decayed roots	Percentage healthy or only doubtfully decayed
Controls	112	150	0	11	89
	113	50	2	6	92
	114	50	0	16	84
	119	30	0	0	100
Pythium debaryanum	112	160	10	74	16
	113	30	7	46	47
	114	40	0	92	8
	119	30	0	83	17
Corticium vagum	112	200	1	34	65
	113	20	0	10	90
	114	50	0	92	8
	119	30	0	57	43
Fusarium spp. F. moniliform species and section	112	100	1	26	73
	113	10	20	20	60
	114	20	5	85	10
	119	20	0	15	85
F. acuminatum	112	20	0	35	65
F. sporotrichioides	112	20	100	0	0
	114	10	100	0	0

TABLE I (Continued)

Summarized Results of the Experiments

Inoculating fungus	Experiment number	Number of seedlings inoculated	Percentage with wholly decayed root system	Percentage with partially decayed roots	Percentage healthy or only doubtfully decayed
F. arthrosporioides	112	20	0	40	60
	113	10	10	30	60
	114	10	70	20	10
F. discolor sulphureum	112	20	80	15	5
	113	10	100	0	0
Conidial stage of Gibberella saubinetii?	112	20	0	35	65
	114	10	0	90	10
Average Fusarium species	112	200	19	26	55
	113	30	43	17	40
	114	50	26	66	8
	119	20	0	15	85
Botrytis (Large sclerotial form)	112	40	63	37	0
	113	10	100	0	0
	114	10	0	100	0
Botrytis (Small sclerotial form)	112	20	0	50	50
	114	10	0	80	20
Rheosporangium aphanidermatus	112	20	0	10	90
	113	10	0	0	100
Phomopsis juniperovora	112	20	75	20	5

than they did in Hartley's (4) experiment, they still caused enough to confirm his statement that *Corticium vagum* is able to cause root rot (Tab. 2).

Fusarium spp. In experiment number 112, the number of seedlings with undecayed roots in the average control was greater than in the average Fusarium pot; in number 113 twice as great; in number 114, ten times as great; and in number 119 slightly greater. In every case

the moniliform section contained fewer seedlings with undecayed roots than the average control, but more than the average Fusarium pot. Strain number 249, seemed to cause more injury than it did in Hartley's (4) late damping-off experiment (Tab. 2). *Fusarium acuminatum* E. and E., *F. arthrosporioides* Sherb. and *Gibberella saubinetii* ? (Dur. & Mont.) Sacc. seemed slightly parasitic, while *F. discolor sulphureum* (Schlecht.) Ap. & Wr. and *F. sporotrichioides* Sherb. were decidedly parasitic. Both of the latter caused late damping-off as well as root rot. Gifford (2) as mentioned above has previously found a species of Fusarium causing root sickness of 2 year old white pines.

TABLE 2

Comparison of results obtained by these methods with those formerly obtained by Hartley (4) on Pinus resinosa

	Hartley's results*		Writer's results	
	No. seedlings inoculated	Per cent healthy or only doubtfully injured	No. seedlings inoculated	Per cent healthy or only doubtfully injured
Pythium debaryanum				
295	57	65	30	37
550	46	72	30	27
810	37	59	20	25
Total	140	66	80	30
Corticium vagum				
147	53	49	20	75
213	44	45	20	50
Total	97	47	40	63
Fusarium moniliforme				
249	32	88	20	65
Controls	115	88	200	89

* Compiled from Hartley's (4) table 10 and the original data from which his table 10 was constructed.

Botrytis spp. The small sclerotial form of Botrytis caused little if any injury to the roots of coniferous seedlings, while the cinerea types (or large sclerotial forms) were decidedly parasitic, injuring practically all of the seedlings. One strain of the latter was able to cause late damping-off.

Rheosporangium aphanidermatus caused no appreciable decay, while *Phomopsis juniperovora* caused considerable decay in one experiment. This together with the results secured with *F. discolor sulphureum* and

F. sporotrichioides suggests the possibility that under conditions favorable to the parasite other fungi as well as damping-off parasites may cause root rot of coniferous seedlings. However, the fact that the damping-off parasites are known to be present in the soil makes them the most probable enemies.

Confirmation of the above statements was secured in general by determining the total number inoculated with each genus and from that recalculating the percentage with undecayed roots and the percentage injured. Table 1 is based upon such recalculated percentages.

Cutting off a portion of the root system did not increase the susceptibility of *Pinus resinosa*. There seemed, on the other hand, to be a slightly decreased susceptibility. This is probably explained by the fact that the fungi usually enter the roots through the young succulent roots which in this experiment were missing. *Pinus resinosa* and *P. banksiana* seemed approximately equally susceptible to *Pythium debaryanum*, but *P. banksiana* seemed on the whole more susceptible to *Corticium vagum* and the *Fusarium spp.* It is impossible to say definitely whether or not these variations were accidental because the number of seedlings was too small to establish relative susceptibility.

These experiments should be repeated under less artificial conditions not only for the purpose of establishing the relative susceptibility of the two hosts, but also for the purpose of definitely establishing the fungi in question as the cause of root rot.[1]

SUMMARY

Roots of *Pinus resinosa* and *P. banksiana* too old to damp-off were inoculated with fungi, mostly damping-off parasites. Inoculum on rice mush was applied directly to the roots, which in most of the experiments were again covered with sterilized sand. A small amount of root rot developed in the controls and a similar amount on a few seedlings inoculated with *Rheosporangium aphanidermatus* and a small sclerotial Botrytis. *Corticium vagum* caused a distinct increase in the amount of

[1] In the above experiments the writer used Carl Hartley's cultures. He obtained them from the following people: Numbers 906, 908, 916 from D. Atanasoff; 183 from M. F. Barrus; 295, 296, 213, 936 from H. A. Edson; 810 from L. A. Hawkins; 947, 948 from G. N. Hoffer; 944 from W. T. Horne; 187 from Mrs. C. R. Tillotson; 922, 925 from H. H. Whetzel. The remainder of the cultures were isolated by various members of the Office of Forest Pathology. The writer also wishes to thank Dr. Hartley for suggestions and criticism of the work; Rush P. Marshall for making the drawing for figure 1; Miss Helen Johann for identifying Mr. Atanasoff's cultures and C. D. Sherbakoff, who identified cultures numbers 947 and 948 as of the moniliform section, but apparently different organisms.

rot, while *Pythium debaryanum* and the cinerea type of Botrytis caused more or less decay to most of the roots. Strains of *Fusarium spp.* gave variable results, but as a whole in the Fusarium pots root rot was more serious than in the average controls. One strain each of *F. sporotrichioides* and *F. discolor sulphureum* killed nearly all the seedlings. Very serious rot also occurred in a small unit of 20 seedlings inoculated with *Phomopsis juniperovora*.

While it is not to be expected that the results of these very artificial tests are representative of what goes on in ordinary nursery beds, they are taken to indicate that the root sickness commonly found in pine seedlings is at least in part caused by damping-off fungi.

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VIABILITY OF TELIA OF CRONARTIUM RIBICOLA IN EARLY WINTER

PERLEY SPAULDING

An attempt has been made to determine how late in the season the telia of *Cronartium ribicola* may remain viable under natural outdoor conditions. The work was carried on at Bethel, Vermont, a fairly representative locality for northern New England and New York, where winter begins early in the season. The investigations began the 26th of September and continued until the 8th of December, 1921. The latter part of the summer and major portion of the fall in the northeastern states had been abnormally dry. Snow fell on November 7 and remained on the ground until November 19. Snow again fell within a few days and was still on the ground when the studies were discontinued, so that winter weather prevailed for a full month before the final tests were made.

The experiments were carried out as follows: Vigorous living Ribes leaves bearing an abundant supply of telia were secured in different localities, as follows: *Ribes nigrum*, *R. odoratum* and *R. americanum* from Block Island, Rhode Island, *R. rotundifolium* from North Hudson, New York, and *R. cynosbati* from Bethel, Vermont. The telia were germinated by placing the leaves upside down in Petri dishes with wet absorbent cotton and filter paper in the bottom beneath the leaves and wet filter paper in the cover above the leaves. The dishes were kept in an unheated room except for the last three tests (Tab. 1), when it was decidedly below freezing out of doors. In these cases the dishes were kept in a moderately warm room. The leaves were enclosed in mosquito netting bags and hung out of doors. Tests were made on September 26, October 3, 21, and 29, November 8, 21, and 30, and December 8. The results shown in table 1 are: telia on *Ribes cynosbati*, *R. rotundifolium*, and *R. odoratum* nearly reached their limit of viability, the latter being the only one which showed some germination on December 8. Those on *R. americanum* retained considerable vigor on this date and apparently were good for a considerable period longer. The outstanding feature of the results, however, were those obtained with *R. nigrum*. Telia collected September 21 still germinated vigorously on December 8. Other telia collected October 11 were almost as vigorous on December 8 as when they were first collected. (Tab. 1.)

Some miscellaneous observations and tests of freshly collected telia, as shown in table 2, help to completely show the significance of these results. In the dry weather of September and October, it was noted repeatedly that telia located upon dead leaves or dead spots of living leaves gave no germination. (Tab. 2.) This was true not only of species like *R. cynosbati* and *R. rotundifolium*, but was also true of *R. nigrum*. At the same time vigorous living leaves on the same bushes bore telia which were strongly viable. It was also found that fresh green leaves

TABLE 1

Longevity of telia of Cronartium ribicola kept out of doors under natural conditions

	Telia from						
	R. nigrum	R. cynosbati	R. rotundifolium	R. nigrum	R. odoratum	R. americanum	R. rotundifolium
Date collected	S 21	S 25	S 29	O 11	O 11	O 11	O 11
	Results of Tests						
Tested Sept. 26	xxx*	x					
Tested Oct. 3	xx	No test	x				
Tested Oct. 21	xxx	x	x				
Tested Oct. 29	xxx	x	x	xxx	x	xx	xx
Tested Nov. 8	xxx	xx	0	xxx	x	xx	x
Tested Nov. 21	xx	x	0	xxx	x	xx	xx
Tested Nov. 30	xx	0	0	xxx	x	x	0
Tested Dec. 3	xx	0	No test	xxx	x	x	0

*xxx Maximum germination
xx Medium germination
x Light germination
(x) Very slight germination
0 No germination

bearing telia, plucked from the bushes and allowed to air-dry naturally, bore telia which germinated strongly. This suggested the conclusion that telia upon leaves that were killed suddenly would retain all of their original viability and that leaves thus killed suddenly by frosts would be found to bear telia of maximum germinating powers. When

frosts finally came, this proved to be the case. It is well known that subjection to cold temperatures approximating freezing stimulates germination of all the different forms of spores of *Cronartium ribicola*. Disregarding *R. nigrum* from consideration, telia on *R. cynosbati* were no stronger in germinating power than those on any other species of

TABLE 2

Vigor of telia of Cronartium ribicola under varying conditions at the time of collection. Test made immediately after collection

Specimen	Collected		Tested	
R. nigrum, vigorous leaves.	Block Is., R. I.	Sept. 21	Sept. 26 Oct. 1	xxx xxx
R. cynosbati, vigorous leaves.	Bethel, Vt.	Sept. 25	Sept. 26	xx
R. cynosbati, dying leaves.	Bethel, Vt.	Sept. 25	Sept. 26	0
R. cynosbati, dead leaves.	Bethel, Vt.	Sept. 25	Sept. 26	0
R. rotundifolium, vigorous leaves.	No. Hudson, N. Y.	Sept. 29	Oct. 1	x
R. nigrum, vigorous green leaves.	Wilmington, N. Y.	Sept. 28	Oct. 7	xx
R. nigrum, fallen, dead, and dying leaves.	Wilmington, N. Y.	Sept. 28	Oct. 1	0
R. nigrum, dead leaves on plant.	Wilmington, N. Y.	Sept. 28	Oct. 1	(x)
R. cynosbati, vigorous leaves.	Bethel, Vt.	Nov. 12	Nov. 12	xxx
R. cynosbati, dead leaves under snow.	Bethel, Vt.	Dec. 1	Dec. 1	0
R. cynosbati, leaves killed by frost and lying on snow.	Bethel, Vt.	Germinated naturally xxx Dec. 3		

*xxx Maximum germination
xx Medium germination
x Light germination
(x) Very slight germination
0 No germination

Ribes tested, yet leaves of *R. cynosbati* which remained upon the bushes until December, although frozen, yielded strongly germinating telia,

as late as December 3. (See Tab. 2.) Such leaves were collected which had dropped to the surface of the snow a short time before and the telia thereon had germinated naturally with maximum vigor. It was noted that diseased leaves of *R. nigrum* and *R. cynosbati* when dried almost invariably rolled their edges upward so that the entire lower surface of the leaf was exposed, thus insuring a maximum distribution of sporidia of the telia thereon.

Since early in the investigations of this fungus and the disease caused by it, it has been recognized by many investigators that *R. nigrum* is far the most dangerous species of Ribes known. It is dangerous as compared with other species because: (1) The plant is nearly maximum in height. (2) It is maximum in vigor of growth. (3) It produces new growth throughout the season. (4) It produces new shoots and leaves to a maximum lateness in the season. (5) It produces a maximum area of leaf surface. (6) It is more susceptible than any other species. (7) A maximum number of telia per unit of leaf area are produced upon this host. (8) These telia are of maximum vigor in germination and production of sporidia. (9) As shown by the above investigations, the telia produced on this host are of maximum longevity in the season. The actual danger from *R. nigrum* varies greatly in different localities because of the great variation in the number of bushes that have been planted there. One region, like the infected section of Washington, will have relatively large numbers, while other places, like the Adirondacks, will have very few or none.

Finally, attention should be called to the fact that these investigations show that telia upon *Ribes nigrum* and, to a lesser extent, upon *Ribes americanum* and *Ribes cynosbati* will remain alive in the winter and will germinate readily when the temperature rises a few degrees above freezing, as shown by the natural germination of telia on *R. cynosbati* leaves on December 3 when lying on the snow. The danger of infection of pines, as indicated by the presence of germinable sporidia, extends indefinitely into the winter in northern New England. It remains to be determined, however, whether the pines are in such condition at this time of year as to become infected.

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INSECTS AS DISSEMINATORS OF PLANT DISEASES. I. RESULTS OF PAST INVESTIGATIONS[1]

FREDERICK V. RAND

I am unable to disclose anything particularly new at this time since my remarks are limited to the results of past endeavor. However, some of the facts to be presented, though not new, are none the less startling in their import. Just thirty years ago, in the year 1891, Waite gave the first demonstration of the insect dissemination of any disease, plant or animal, caused by micro-organisms when he showed that in nature the spread of the bacterial fireblight of pomaceous fruit trees is brought about almost exclusively through the agency of insects. Two years later Theobald Smith and Kilborne put forth their experimental proof that Texas fever is transmitted by the cattle tick (*Ixodes bovis* Riley); and soon thereafter Erwin F. Smith gave experimental evidence of some of the insect relations of several diseases of plants, bacterial in their nature. During the approximately three decades following these early endeavors the interrelations and correlations between pathogenic micro-organisms and insects for the spread of disease have received steadily increasing attention at the hands both of plant and animal pathologists and entomologists.

It is difficult to give in a very limited space any adequate conception of the mass of evidence thus far accumulated as showing the really important rôle played by insects and certain small arachnids either in the direct distribution of the micro-organisms of plant disease, or in the providing of wounds for their ready entrance into the host tissues. Two years ago, in preparing the manuscript, "A Coordination of our Knowledge of Insect Transmission in Plant and Animal Diseases," by Rand and Pierce (later published in Phytopathology **10**: 189–231, 1920),[2] we attempted to classify the different types of insect transmission. This we did with the full knowledge that here as elsewhere in biology no hard and fast lines can be drawn. However, several distinct methods do exist and we believed that such a classification would serve a useful purpose in the mental grouping of insect relations to pathogenic diseases.

In the dissemination of the bacterial fireblight of apples and pears by bees or of the fungous internal boll disease of cotton by several sucking insects the causal organisms are carried in or on the mouth parts or other external portions of the insect body and are directly inoculated into the plant host under conditions suitable for parasitic growth. In some cases of this kind there is a distinct insect adaptation, beneficial to the plant parasite, although the insect concerned is in no sense an intermediate host or reservoir for the parasitic organism. On the other hand, in the dissemination of the bacterial heart and rib rot of cabbage caused by *Bacterium campestre* (Pam.) EFS by flies and in a large part of the spore dispersal by various insects in the case of the chestnut blight fungus the organisms, carried in a viable condition mostly on the insect bodies, are accidentally sown rather than directly inoculated or "put into" the host tissues.

[1] Paper read at the joint session of the Phytopathological Society and the American Association of Economic Entomologists, Toronto, Canada, December 31, 1921.

[2] The writer has in preparation a review which will bring this paper up to date. Separates and suggestions will be appreciated.

In other cases, as in the bacterial boll rot of cotton and in many of the chestnut blight infections the role of insects consists in the provision of points of entry for infective material brought there by other agencies than the particular insect making the wounds.

In still other instances, as in the Leptosphaeria fungus causing apple canker and raspberry cane blight, the spores are carried not only superficially but remain viable after passage through the digestive tract of the insect. Although the relation here is merely a mechanical one there is nevertheless thus afforded a double chance for infection to be effectively brought about.

However, the clearest cases of adaptation for disease transmission are found where the infective principle obtains within the insect body conditions favorable for further development or multiplication. Among bacterial diseases of plants such a relation has been shown to occur between the olive-knot organism and the olive-fly (*Dacus oleae* Rossi) as worked out by Petri; and between the bacteria of cucurbit wilt and the striped cucumber beetle as shown by my own work in collaboration with Enlows and Cash.

In correlating the published and unpublished data at hand relative to cucumber wilt the seasonal history appears to be as follows: A small percentage of striped cucumber beetles come out of winter quarters as "wilt carriers." As they feed upon young cucumber seedlings their feces laden with wilt bacteria become mixed with dew or light rain and are thus brought into the intimate contact with fresh injuries opening into the vascular system which are necessary for any infection to take place. In this manner originate the sporadic primary cases of the disease seen in early spring. Once started in this manner the disease is then largely spread from plant to plant through mechanical dissemination by the mouth parts of the voracious and actively flying beetles; and the rise in the disease curve corresponds closely with the increase in the prevalence of these insects during the advancing season. Dissemination by two species of Diabrotica constitutes the only known method by which this disease is spread in nature.

In the various infectious chloroses of plants we have a whole train of diseases or related groups of diseases in which the insect relation is clean cut and often specific. As shown by Ball and later corroborated by others the beet leafhopper (*Eutettix tenella* Baker) is not only the sole means of transmission for the disease but it appears from the work of R. E. Smith and Boncquet that at least twenty-four hours must elapse after feeding on a diseased plant before the insect is capable of giving infection. Carsner and others have demonstrated that this disease is readily intercommunicable as carried by leafhoppers among a considerable number of other cultivated hosts and wild plants. McClintock and Loren B. Smith have transmitted spinach blight by the tarnished plant bug and by three species of aphids, and have carried the infective principle through four generations of aphids after one feeding of the original parents on blighted spinach. Similar transmission of mosaics or other chloroses of potato and tobacco, of the cabbage and clover families, of sugar cane and other members of the grass family, of red raspberry and many other hosts and groups of hosts are now familiar to all workers on this type of disease. Doolittle and his collaborators have shown that an important part of cucumber mosaic transmission is not only through the agency of sucking insects but also by means of two species of cucumber beetles. Furthermore, through the use of one or the other of these insects he has carried over the malady not only to various wild and cultivated members of the cucurbit family but apparently also to pokeweed and potato.

TABLE 1

Insect dissemination of plant diseases[1]

Mode of dissemination	Bacterial			Fungous			Protozoan	Filterable contagium	
	Experimental proof	Strong circumstantial evidence	Doubtful	Experimental proof	Strong circumstantial evidence	Doubtful		Experimental proof	Strong circumstantial evidence
External dissemination and direct inoculation	6		1	3	9			(1)	
External dissemination without direct inoculation	(1)	3		4	8 (1)	1			
Wound infection from other sources than the wounding agent	1	3		2 (1)	6				
Internal mechanical (unchanged passage)				5	2				
Internal biological (Multiplication within carrier)	2	1		2			1	59 Host	7
	9	7	1	16	25	1	1	59	7

[1] Figures in parentheses indicate that the disease has also been enumerated under another type of insect dissemination.

The fact that the leaf that is punctured on the sugar beet is not the one that shows the disease, but the leaf that is growing, shows that whatever is injected into the sugar beet passes down into the beet root itself, and then back up into the leaf.

Not only that, but if you cut all the leaves off the beet, the leaves that come up again will be diseased. If you silo the beet over winter and grow a seed beet next year, it will be diseased, showing that the whole organization of the sugar beet has been infected, and a rather rapid transportation of that infection from part to part of the sugar beet.

When you come to the tipburn or hopperburn of the potato you get a different situation, for there is no movement of the disease in the potato. The leaf that is attacked is the one that is injured, and no other. The disease is not in any sense progressive. The leafhopper that attacks a single leaf has no effect on any other leaf of the potato, up to the time of the death of the plant.

I have not been able to take the time to trace out the relationships in this newest of our discoveries on the cane mosaic. The spinach mosaic does not appear to be specific. There are two species of plant lice and one of tarnished plant bug that have transmitted this disease. So that leaves that in a doubtful category at this time.

It may be interesting for you to note one thing about these insects. I know nothing at all about the life history, except in a general way, of the false chinch bug. Let us take the two diseases we have here—the beet leafhopper and the potato leafhopper. There is at once a remarkable thing about both of them. The insects winter over as adults in both cases, and that is rather exceptional in leafhoppers. The females that pass the winter live until late in the summer and some of them to the frost period in the fall. Dr. Fenton and Mr. Hartzell kept one of these insects until September 7th; that was undoubtedly developed as an adult during July or August of the year previous. This particular insect laid eggs up until almost the end of that period, laying one hundred forty-two eggs, an average of one egg a day.

The potato leafhopper does not have time to complete the second brood under the climatic conditions of central Iowa. The beet leafhopper in the regions where I studied it, is a single generation insect, and normally the great majority of those remain in the sugar beet field until very late in the season, laying eggs through a period of time long enough for three generations of the insect to have matured if it had an ambition to have numbers of generations.

The same thing is true of the potato leafhopper. Just exactly what relation this extreme length of life has to the problem is not quite clear. The fact that it lives over winter as an adult may be necessary in order that it carry the disease over winter. In other words, it does not, in the case of the beet leafhopper, transmit this disease through the egg. If you take a beet leafhopper as it comes out of the egg, before it has had time to turn around and suck the diseased plant from which it was hatched it does not carry the disease.

In hunting for the solution of these problems it appears that we ought to keep in mind the fact that the chances are very great that the insect that transmits any one of them will be one that hibernates as an adult; that in a case of specific transmission it will probably be a sucking insect, and an insect with a long adult life. The reason for this last conclusion is not clear.

There is, of course, the possibility that under wild conditions with a large number of generations, that a generation might be compelled to migrate to a plant that did not carry the disease, and then the generation that came back would be without it. Unless the disease is of some advantage to the insect there is no reason for that inference, but in the case of the beet leafhopper the disease is apparently an advantage to the insect. The beet leafhopper has a half dozen relatives that produce the same

type of injury on the sunflower, the pigweed and other related weeds, and in every instance, the color of the malformation on the leaf is the color of the larvae of the insect and this color together with the curling serves as a protection.

The potato leafhopper is a native of South America, but has spread to North America and is now appearing in Europe so that tipburn may be expected to spread to other regions. The beet leafhopper is a native of the arid southwest and the curly leaf is at present confined to that region.

I have occupied more time than I should in bringing out some of the points that we should keep in mind in studying this problem from the insect standpoint. (Applause.)

INSECT AS DISSEMINATORS OF PLANT DISEASES. III. CONTROL PROBLEMS[1]

L. CAESAR

I have been asked by the committee in charge to introduce the control problem aspect of this morning's program and do so with much diffidence, partly because of lack of sufficient familiarity with the diseases and partly because of pressure of other duties which have prevented my giving the thought to the subject that it required. I shall not attempt to outline methods of control for any disease but will mention some of those proposed by different persons or that have suggested themselves to me, then refer to some difficulties that beset control and finally discuss the insect aspect of the problem.

The following are the general recommendations for control as outlined by investigators or as inferred from what we know of the life histories of the diseases: First, remove and destroy promptly all infected plants beginning as early in the season as the symptoms of the disease disclose themselves. Second, ward off or destroy insect disseminators. Third, take the necessary precautions against spreading the diseases during the growing season by mechanical means such as pruning, harvesting and careless cultivation. Fourth, destroy at once after harvesting the crop all remnants, if there is any suspicion that these may be a source of danger. Fifth, select seed wherever possible from plants known to be healthy. (Do the same with tubers in the case of potatoes.) Sixth, endeavour to find and remove the source of primary infection in spring whether it be other host plants of the disease, especially perennial weeds, or some other source. Seventh, take precautions to secure and maintain healthy seedlings in spring. (This is more or less covered by some of the preceding.) The securing of healthy seedlings or other sources of plants such as tubers may of course involve special isolated seed plots, carefully inspected and protected throughout the season. Eighth, the discovery and selection where possible of immune varieties.

Now let me call your attention to some of the great obstacles to carrying out the above. First, we have not sufficient knowledge of the relationship between the different diseases themselves (I refer particularly to mosaic diseases). For instance, is the mosaic of potato a distinct disease from that of tomato and of cucurbits? This is an exceedingly important matter and there still seems to be some doubt about it. Second, we evidently do not yet know all the wild host plants of the different diseases, more being

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	9	7	1	16	25	1	1	59	7

[1] Figures in parentheses indicate that the disease has also been enumerated under another type of insect dissemination.

This is hardly the place for a discussion as to the nature of the causal agents in these diseases or of their relations to each other. However, the similar sequence of symptoms, both external and internal, and the progressive connecting up by different workers of various groups of host plants among which mosaic is intertransmissable surely suggests a probability that the causal agents of infectious mosaics are closely related. Furthermore, in some cases at least, the data at hand suggest that the insect may be not merely a mechanical carrier but should be considered as a true intermediary host of the infective contagium.

Odious though statistics often may be, perhaps the clearest way to show briefly what has been done by entomologists and pathologists relating to insect dissemination of plant diseases is by means of a numerical summary. Using the data which I have gleaned from the literature a table has been prepared showing the number of diseases, —bacterial, fungous, protozoan and filterable contagium,—carried by the different types of insect dissemination. The figures are not to be considered as absolute since new investigations will, of course, continually change our outlook, and some work already published may have been overlooked. For full proof of insect dissemination in any specific case I have considered it necessary to show that under natural conditions the insect is in the habit of visiting both diseased and healthy plants, of carrying the causal contagium and depositing it in places favorable for infection, and that infections actually do thus result in nature. If any of these steps have been omitted, even though the evidence is rather clearly incriminating, I have placed the disease under the "circumstantial evidence" column in the table.

To summarize briefly (cf. Tab. 1), then, full proof is forthcoming for nine bacterial diseases. This is followed by strong circumstantial evidence in seven other cases and rather doubtful evidence in the one remaining case. This represents sixteen or seventeen bacterial diseases in which insect dissemination in one form or another plays a part. Among fungous diseases of plants the proof is definite for sixteen diseases, followed by strong evidence for twenty-five and doubtful evidence for one—or a total of forty-one or forty-two. In one protozoan disease, a flagellosis in the latex of certain Euphorbias (caused by *Leptomonas davidi* Lafont), Lafont has shown the sucking insect, *Nysius euphorbiae* Horvath. to be a true intermediate host. Most of the flagellates of this group are normal inhabitants of insects.

In the case of the mosaic group of diseases I have found fifty-nine hosts for which insect transmission has been fully demonstrated and seven where the circumstantial evidence is strong, making a total of at least sixty-six hosts where insects spread mosaic.

Among the bacterial and fungous diseases of plants insect dissemination, where it occurs, is in some cases sporadic and incidental. In a considerable number of these diseases, however, as for example, in the fireblight or in the English blossom blight of pomaceous fruit trees and in cucurbit wilt among bacterial diseases, and in the cotton internal boll disease, carnation bud rot, pineapple Thielaviopsis, chestnut blight, apple Leptosphaeria canker, corn stalk and ear molds and many other fungous diseases, insects bear a really important relation to the spread of disease, either directly as actual carriers of infection or indirectly by their provision of wounds through which the organisms may enter. It is, however, among the infectious chloroses, including the mosaics, that we find whole groups of diseases where insects appear to be the principal and in some instances the only means of spreading the disease in nature. Their importance in this connection, therefore, can hardly be overestimated.

INSECTS AS DISSEMINATORS OF PLANT DISEASES. II. SYSTEMATIC RELATIONS OF CARRIERS[1]

E. D. Ball

Mr. Rand has given you a resumé of the whole subject. I only want to add to that a little analysis of the insects included. This may be more for the benefit of the pathologists. A study of a large number of these insect disseminated diseases will develop the fact that the insect contact is entirely accidental. That is, any insect that lights on a pear tree and sucks the juices may carry pear blight, and a large number of cases occur in which there is no adaptation on the part of the insect, or any peculiar type of insect required for this distribution.

When you come to the cucumber mosaic, and the cucumber wilt, the carrying over winter of this disease by the beetle infers something a great deal more definite and important than the other type of transmission. There must be a multiplication of the bacteria in the intestinal tract or in the body cavity (the body fluid) of that insect to maintain this disease in a viable state for so long a period of time.

The actual transmission to the plant is shown to be entirely accidental, due to the excreta being distributed over the tissues of the plant and coming in contact with the cut surfaces made by the feeding of the beetle, but we must have a conception of an adaptation of this germ to a life in the insect during the hibernating period, and even longer than that.

That opens up a new field and you will note there that the cucumber beetle is a leaf feeding, a biting insect, but that the transmission as far as the mechanical part of the insect is concerned, is entirely accidental. It is not transmitted apparently through the mouth, but through the feces.

In Rand's second division we get to a relation that is obligatory. In the case of the Euphorbia plant the little false chinch bug which is a sucking insect deposits saliva in the wound, and with it one stage of the organism. There is a stage of the development of the protozoan parasite in the insect and another in the milky juice of the Euphorbia—a typical case of a transmission of a plant disease in exactly the same way that a large number of animal and human diseases are transmitted. That suggests the possibility that we will find a number of protozoan diseases in plants before we are through.

When we come to the curly top of the sugar beet—there we get a transmission which is absolutely specific again, but there is only a single species of insect (though there are a number of that same group of insects that feed on sugar beets) that is able to carry that disease over winter, and reproduce it on the sugar beet. Nothing more seems to be known about what it carries or how it is carried except that he is not able to transmit the disease immediately after he has punctured a diseased beet. It takes an incubation period usually of two or more days. That may be entirely mechanical. It may be simply the time required for the passage from the alimentary canal back through the salivary glands, and to a point where it can be passed to the new plant. Many of the facts indicate an incubation stage in the insect such as we find in protozoa parasites.

[1] Paper read at the joint session of the Phytopathological Society and the American Association of Economic Entomologists, Toronto, Canada, December 31, 1921.

The fact that the leaf that is punctured on the sugar beet is not the one that shows the disease, but the leaf that is growing, shows that whatever is injected into the sugar beet passes down into the beet root itself, and then back up into the leaf.

Not only that, but if you cut all the leaves off the beet, the leaves that come up again will be diseased. If you silo the beet over winter and grow a seed beet next year, it will be diseased, showing that the whole organization of the sugar beet has been infected, and a rather rapid transportation of that infection from part to part of the sugar beet.

When you come to the tipburn or hopperburn of the potato you get a different situation, for there is no movement of the disease in the potato. The leaf that is attacked is the one that is injured, and no other. The disease is not in any sense progressive. The leafhopper that attacks a single leaf has no effect on any other leaf of the potato, up to the time of the death of the plant.

I have not been able to take the time to trace out the relationships in this newest of our discoveries on the cane mosaic. The spinach mosaic does not appear to be specific. There are two species of plant lice and one of tarnished plant bug that have transmitted this disease. So that leaves that in a doubtful category at this time.

It may be interesting for you to note one thing about these insects. I know nothing at all about the life history, except in a general way, of the false chinch bug. Let us take the two diseases we have here—the beet leafhopper and the potato leafhopper. There is at once a remarkable thing about both of them. The insects winter over as adults in both cases, and that is rather exceptional in leafhoppers. The females that pass the winter live until late in the summer and some of them to the frost period in the fall. Dr. Fenton and Mr. Hartzell kept one of these insects until September 7th; that was undoubtedly developed as an adult during July or August of the year previous. This particular insect laid eggs up until almost the end of that period, laying one hundred forty-two eggs, an average of one egg a day.

The potato leafhopper does not have time to complete the second brood under the climatic conditions of central Iowa. The beet leafhopper in the regions where I studied it, is a single generation insect, and normally the great majority of those remain in the sugar beet field until very late in the season, laying eggs through a period of time long enough for three generations of the insect to have matured if it had an ambition to have numbers of generations.

The same thing is true of the potato leafhopper. Just exactly what relation this extreme length of life has to the problem is not quite clear. The fact that it lives over winter as an adult may be necessary in order that it carry the disease over winter. In other words, it does not, in the case of the beet leafhopper, transmit this disease through the egg. If you take a beet leafhopper as it comes out of the egg, before it has had time to turn around and suck the diseased plant from which it was hatched it does not carry the disease.

In hunting for the solution of these problems it appears that we ought to keep in mind the fact that the chances are very great that the insect that transmits any one of them will be one that hibernates as an adult; that in a case of specific transmission it will probably be a sucking insect, and an insect with a long adult life. The reason for this last conclusion is not clear.

There is, of course, the possibility that under wild conditions with a large number of generations, that a generation might be compelled to migrate to a plant that did not carry the disease, and then the generation that came back would be without it. Unless the disease is of some advantage to the insect there is no reason for that inference, but in the case of the beet leafhopper the disease is apparently an advantage to the insect. The beet leafhopper has a half dozen relatives that produce the same

type of injury on the sunflower, the pigweed and other related weeds, and in every instance, the color of the malformation on the leaf is the color of the larvae of the insect and this color together with the curling serves as a protection.

The potato leafhopper is a native of South America, but has spread to North America and is now appearing in Europe so that tipburn may be expected to spread to other regions. The beet leafhopper is a native of the arid southwest and the curly leaf is at present confined to that region.

I have occupied more time than I should in bringing out some of the points that we should keep in mind in studying this problem from the insect standpoint. (Applause.)

INSECT AS DISSEMINATORS OF PLANT DISEASES. III. CONTROL PROBLEMS[1]

L. CAESAR

I have been asked by the committee in charge to introduce the control problem aspect of this morning's program and do so with much diffidence, partly because of lack of sufficient familiarity with the diseases and partly because of pressure of other duties which have prevented my giving the thought to the subject that it required. I shall not attempt to outline methods of control for any disease but will mention some of those proposed by different persons or that have suggested themselves to me, then refer to some difficulties that beset control and finally discuss the insect aspect of the problem.

The following are the general recommendations for control as outlined by investigators or as inferred from what we know of the life histories of the diseases: First, remove and destroy promptly all infected plants beginning as early in the season as the symptoms of the disease disclose themselves. Second, ward off or destroy insect disseminators. Third, take the necessary precautions against spreading the diseases during the growing season by mechanical means such as pruning, harvesting and careless cultivation. Fourth, destroy at once after harvesting the crop all remnants, if there is any suspicion that these may be a source of danger. Fifth, select seed wherever possible from plants known to be healthy. (Do the same with tubers in the case of potatoes.) Sixth, endeavour to find and remove the source of primary infection in spring whether it be other host plants of the disease, especially perennial weeds, or some other source. Seventh, take precautions to secure and maintain healthy seedlings in spring. (This is more or less covered by some of the preceding.) The securing of healthy seedlings or other sources of plants such as tubers may of course involve special isolated seed plots, carefully inspected and protected throughout the season. Eighth, the discovery and selection where possible of immune varieties.

Now let me call your attention to some of the great obstacles to carrying out the above. First, we have not sufficient knowledge of the relationship between the different diseases themselves (I refer particularly to mosaic diseases). For instance, is the mosaic of potato a distinct disease from that of tomato and of cucurbits? This is an exceedingly important matter and there still seems to be some doubt about it. Second, we evidently do not yet know all the wild host plants of the different diseases, more being

[1] Paper read at the joint session of the Phytopathological Society and the American Association of Economic Entomologists, Toronto, Canada, December 31, 1921.

found every year. Not to know these is to be greatly hampered in finding control measures, especially as perennial weed hosts may serve as a method of overwintering of the disease and thus as the primary source of infection in spring. Third, in a few cases there still seems to be some doubt whether certain of the diseases may not overwinter in the seed bed or in the soil and become the primary source of spreading the disease in spring. Lastly we need more definite knowledge of the cause or causes of the great fluctuations of some of the diseases from year to year. The absence or presence of insect disseminators does not appear to be the solution of these fluctuations, for instance, many of us have observed the remarkable absence of potato mosaic some years and its prevalence other years. Professor Howitt tells me that so far as his experience goes mosaic is every year present and its symptoms quite evident in northern Ontario. What is the explanation? Is it that the disease is present in southern Ontario and other places annually but that some years its symptoms are suppressed, or is there some other factor that we have overlooked?

From these and other considerations it is evident that the greatest aid to the final solution of control problems lies in further life history studies. This, of course, is no justification for our not trying in the meantime whatever control measures appeal to our judgment and securing from them what light we can.

In turning to the insect aspect of our subject we are all agreed I suppose that by warding off the insect transmitters the control of the diseases in question would be made much simpler and perhaps in the majority, or possibly all, of the cases solved. But satisfactory insect control is with a few exceptions so difficult and so costly that it is doubtful whether in the long run we shall not have to find some other way of accomplishing our purpose. The only insect-produced disease that I can think of at present that has been simply and satisfactorily solved by insect control is the hopperburn of potatoes. This disease is of a simpler type than mosic or any of the others. Bordeaux mixture acts as a repellant for the leaf hoppers and thus protects the plants, and, as Bordeaux is used in any case in good potato culture, the extra cost of controlling the insects is very little.

The striped cucumber beetle is apparently the sole transmitter of cucumber wilt and an important agent in the spread of the mosaic on cucurbits. Control measures for this insect as known at present are merely helpful and far from satisfactory. Our duty here evidently is to begin a new study of the insect and discover if possible a thoroughly satisfactory means of combating it.

Several species of aphids are the main agents in transmitting the various mosaic diseases, leaf roll, raspberry leaf curl and spinach blight. The control of these aphids is rendered very difficult, especially some years, by the following obstacles: First, they are marvellously prolific: scarcely any other kind of insect can compare with them. At first there may be only a few scattered individuals in the plot but in a few weeks these sometimes will have increased to millions. Second, most of the species involved have many host plants; for instance, the peach aphis, *Myzus persicae*, and the potato aphis, *Macrosiphum solanifolii* have each more than fifty different host plants, most of them being weeds, and yet these are two of the most important aphids involved in the diseases referred to. Hence, while we are trying to protect a certain kind of plant these aphids may be breeding everywhere in the surrounding vicinity. Third, throughout most, or in some cases almost all, of the growing season there are both winged and wingless forms of the insect. The wingless forms travel slowly but the winged forms, one of whose functions seems to be to distribute the species, move freely from place to place; so that no matter how clean a plot may be one week it is likely to be reinfested the next. Fourth, aphids have the habit of rolling leaves and working under the protection of the rolled area where it is very difficult to reach them

with spray mixtures. This makes treatment slower and more costly. Fifth, sprays for aphids are of the contact type, killing either by hitting or by the fumes given off, hence their effect lasts only for a few days at the most, this means that they have to be repeated frequently. Moreover, nicotine used either in the liquid or dust form is the only efficient insecticide at present available and is very costly, hence numerous applications of it would mean that the grower in at least many cases would prefer to give up the crop rather than face the trouble and expense.

Such then are the difficulties involved in the control of the aphid transmitters. All of these difficulties, however, are not always active and so the task sometimes is not nearly so hard as it looks. For instance, the following favoring conditions sometimes act on our side and render control practicable: First, in a hot season the aphids usually disappear, or almost disappear, during July and August. Second, some years the various factors that help to control aphids are very powerful throughout the whole season and so reduce their numbers that very few are present at any time. Third, some of the plants in question, as for example, tomatoes and tobacco, are not as a rule favorite hosts of aphids. Lastly in the case of raspberry leaf curl, transmitted by *Aphis rubiphila*, as discovered by Dr. Rankin, the insect under field conditions seems to be wingless and to move about very little. Dr. Rankin has found that as a result of this he has been able by early roguing of infected plants to control the disease without having to fight the aphids.

In conclusion, without discussing the tarnished plant bug, which is the other main offender and for which we have no satisfactory control, I shall merely call attention to the fact that the study of the relation of insects to these diseases has emphasized our need of an efficient and cheap contact insecticide for aphids and other sucking insects such as leaf or plant bugs.

INSECTS AS DISSEMINATORS OF PLANT DISEASES. IV. URGENT PROBLEMS OF THE FUTURE[1]

MAX W. GARDNER

In order to be able to call to your attention some of the really urgent problems of the future in connection with insects as disseminators of plant diseases, I have made an effort to ascertain the opinions of a number of pathologists and entomologists who have conducted research along this line and have attempted to correlate and summarize the information thus acquired.

All of us are, I assume, primarily interested in being of real service to the growers of agricultural crops, in increasing the production per acre, and last but not least in serving science. I choose to avoid further generalities and to be as specific as possible in the short time allotted.

I believe I am safe in asserting that comparatively few types of plant disease are more or less strictly dependent upon insects for their dispersal. From an economic point of view based upon the importance of the crop and the prevalence and destructiveness of the disease, I believe we can safely eliminate from this category practically all of the fungous diseases and all but a few of the bacterial diseases and concentrate our attention upon the really important insect-borne diseases. Permit me briefly to dispose of two outstanding cases among the bacterial diseases, namely, fire blight of apples and pears and wilt of cucumbers and cantalcupes.

[1] Paper read at the joint session of the Phytopathological Society and the American Association of Economic Entomologists, Toronto, Canada, December 31, 1921. Contribution from the Botanical Department, Purdue University Agricultural Experiment Station, LaFayette, Indiana.

Smith (31 p. 215) and Rand and Enlows (25) have shown that cucumber wilt is strictly dependent upon the striped and spotted cucumber beetles for both dissemination and overwintering of the pathogene. Here, it would seem, pathologists have done all within their power for the present, all further progress being dependent upon the development of a more perfect control of the two species of beetles.

The fire-blight situation is more complex. Recent work in Ohio (15) and in Illinois (34) on rain drip and wind-blown-rain infection and by Heald (16) on leaf water-pore invasion indicates that possibly too much emphasis has been placed on the insect relations. The whole situation should receive further study by pathologists with a view to the improvement of blight-control by some such measures as spraying and the development of resistant varieties. The root and collar blight in the Northwest and the mode of transmission from such lesions to the blossoms presents a problem to both entomologists and pathologists.

There remains for our consideration a rather homogeneous group of very important plant diseases, largely insect-disseminated, and I feel certain that I am correct in assuring you that by far the most urgent need of the present is a better understanding of this group of diseases—the so-called virus or mosaic diseases. Dr. Rand and Dr. Ball have just explained how closely these diseases are associated with certain insects as disseminating agents. When one considers the large number of important crops subject to one or another of this type of disease, and the extreme destructiveness, the rapidity of spread, and the apparent annual increase in the prevalence of these mosaic diseases, their importance can hardly be overestimated. I know of no diseases more baffling and discouraging to the grower and the pathologist.

To attempt, in the time allotted, to give an account of all of the urgent needs in connection with our fragmentary knowledge of these troubles is impossible. This group of diseases offers not only a challenge, but a rare scientific opportunity because of the similarity of the symptoms and behavior in the many different hosts. An advance in the understanding of any one of the mosaics is very likely to throw much needed light upon all the rest. Our understanding of this group of insect-borne diseases stands in the greatest need of painstaking and fundamental research by both pathologists and entomologists.

The investigation of mosaic diseases necessitates a specialized technique which in itself makes it essential that the entomologist and pathologist work in close association in the solution of certain phases of the problem since either one working alone may err seriously. Such investigation also necessitates expensive equipment and the desirability of enabling isolated workers with poor facilities to take their problems to a well-equipped institution at the proper time should be recognized.

I desire to illustrate by specific examples some of the urgent problems presented by the mosaic diseases and I have attempted to arrange these problems in three classes, first, those which it would seem to be the duty of the pathologist to solve, second, those which must be solved by the entomologist, and third, those which will very likely necessitate the combined efforts of pathologists and entomologists. It should be remembered that for certain mosaic diseases some of these problems have already been at least partially solved.

The problems for which the pathologists alone are primarily responsible may be grouped under five headings, as follows: 1. The nature of the mosaic contagium, infective principle, or virus. 2. The physiology of infection. 3. Transmission by other means than insects. 4. Host range of each virus, with especial reference to wild carriers of infection. 5. Development of disease-resistant varieties.

With respect to the nature of the contagium or virus, a number of methods of attack are open which may help us to ascertain whether the causal entity is a lifeless chemical compound or an organism.

By filtration through bacteria-proof filters it has been proved that the causal entity in several mosaic diseases is not of the nature of ordinary bacteria. Allard (3), Doolittle (8, p. 24), and others have shown that the viruses of tobacco and cucumber mosaic will pass the coarser filters such as the Berkefeld type but not the finer filters such as certain Chamberland filters, atmometer cups, and talc layers. Since the viruses of certain human and animal diseases not only pass these finer filters but collodion filters as well, it is evident that the causal entity of plant mosaics is not as finely divided as that of the animal filterable virus diseases. By careful differential filtration with several types of atmometer cups in comparison with certain chemical compounds, Duggar has recently been able to arrive at a close approximation of the size of the active particles in the tobacco mosaic virus.

By the effect of dilution of the juice of a mosaic plant upon its infective power, some idea of the concentration of the causal particles can be obtained. Allard (1) working with tobacco mosaic and Doolittle (8, p. 21) working with cucumber mosaic have found that a dilution of 1:10,000 was about the upper limit at which any infectivity was retained. Animal pathologists report that animal viruses retain their infectivity in very much higher dilutions. The fact that in the case of cucumber mosaic the incubation period is no longer with the diluted than the undiluted juice and that within four days the plant may be completely permeated with the virus indicates a most remarkable power of multiplication and diffusion on the part of the causal entity.

By the use of the ultramicroscope, the range of which extends downward to diameters of about six one-thousandths of a micron, upon the infective filtrates, light may be shed upon the nature of the particles.

Careful cytological study of diseased host cells should yield extremely interesting information. Iwanowski (18) working with tobacco mosaic and Kunkel (20) working with corn mosaic have found evidences of an intracellular organism. The microchemistry of diseased as compared with normal plants might yield instructive data.

The localization of the virus in the various tissues and organs of the host should be studied. Allard's work (2) on the presence of the mosaic virus in various organs of the tobacco plant furnishes an example of work of this character.

The effect of temperature, storage, desiccation, and various hydrogen-ion concentrations upon the virus in vitro and the effect of various reagents and germicides may yield important information concerning the causal factor. The investigations of Allard (3, 4) and later of Doolittle (8, p. 19) along this line have been very suggestive.

Attempts to culture an organism from the virus have only begun. Only a limited range of media has been tested. The possible significance of specific compounds and accessory factors should be considered. Variation of the oxygen and carbon dioxide pressures and of the H-ion concentration in a wide variety of media, including host tissue preparations, might yield interesting results. The strikingly beneficial results of an increased CO_2 tension (17) on the growth of certain animal pathogenes and of a decreased oxygen pressure in the culture of certain human pathogenes is of interest in this connection. The success reported by Flexner and Noguchi (13) with the culture of the virus of poliomyelitis should encourage the plant pathologist.

Duggar (10, p. 288) has suggested that delicate tests should reveal the presence of life activity in the virus in vitro, if it is an organism comparable to any types of which we now conceive.

The work of Löhnis and Smith (21) on the life cycles of certain bacteria and the existence of pleomorphic species is highly suggestive in connection with filterable viruses in general. Rosenow and Towne (28) report that the streptococcus held by them to be responsible for poliomyelitis may under certain conditions become sufficiently reduced in size to pass the filters.

The physiology of infection should be studied with such points in mind as:

1. The effect of age of host, temperature, humidity, and soil conditions on susceptibility, incubation period, and severity of the disease. Recent work by Johnson (19) and by Doolittle on the effect of temperature has yielded striking results.

2. The possibility of the isolation or development of resistant strains or varieties of the host. The resistance of the bean variety known as Robust Pea to mosaic, the development of a mosaic-resistant variety of spinach by Smith (33) at Norfolk, and the discovery (29, p. 28) of a mosaic-resistant strain of the Bliss Triumph potato indicate that resistance may be found in other crops subject to mosaic diseases.

3. The relative susceptibility of certain organs and tissues. In some cases the phloem tissue appears to be particularly susceptible to infection.

To the pathologist falls the study of the mode of transmission by agencies other than insects, by such operations as artificial pollination of greenhouse crops, cultivation, pruning, and picking, and the study of dissemination by the transport of seed or reproductive parts such as tubers and cuttings, of nursery stock, and of transplants. The possibility of mosaic transmission in the pollen has been suggested. The likelihood of control by roguing early sources of infection should be ascertained.

The possibility of the overwintering of the virus in the seed (as in bean and soybean mosaic) or vegetative reproductive parts (as in potato leaf-roll and mosaic and sugar cane mosaic) of the host and how to produce or obtain disease-free seed are the pathologist's problems.

Host range studies are of basic importance. This applies to cultivated crops as well as wild hosts. Mosaics enphytotic in wild hosts may be the original source of these crop troubles and all mosaics in weeds or wild plants should be viewed with extreme suspicion. The question of wild perennial hosts is of vital importance in connection with the mode of overwintering of the virus in the mosaics of certain crops. For example, the perennial ground cherries and horse nettle constitute a reservoir of mosaic infection for the tomato crop (14) and Doolittle and Walker (9) have found that milkweed perpetuates the cucumber mosaic virus. Carsner (7) has found that a winter annual weed (*Erodium cicutarium*) in California carries the beet curly-top virus. The mosaic symptoms may be obscure or lacking in certain of these wild carriers of infection especially in old plants late in the season. In the cases of cucumber mosaic and tomato mosaic, extensive field observations indicate that, once introduced among the perennial weed hosts in a locality, the disease persists year after year and, as new fields are used for the host crops, the reservoir of mosaic infection in the perennial weed flora increases annually. In fact this reservoir of infection may increase at an alarming rate and, as in the case of cucumber pickle growing, drive the industry out of one region after another.

For the solution of many very important questions we are dependent entirely upon the entomologists. Speaking for the pathologists, I may say that in many instances further progress in mosaic control rests wholly with the entomologists. In fact I be-

lieve an appeal should be made to entomologists in general to acquaint themselves with and interest themselves in this group of complex insect-transmitted diseases. Furthermore, pathologists must depend upon entomologists for an explanation of the true nature of such troubles as potato hopperburn which are of insect causation. It is with great hesitation that I venture to make suggestions in a field of science other than my own, but certain needs are outstanding.

In many cases we know that mosaic transmission is accomplished entirely by certain species of aphids or leafhoppers. The obvious necessity in these cases is a really effective control for these particular species, not the degree of control which would be considered satisfactory from the standpoint of actual insect damage, but an absolute control, because one aphis or leafhopper alone may be able to inoculate a plant.

Might not more detailed study be concentrated upon the particular insect species already incriminated as carriers? Such a study should disclose important features in connection with the life history of these carrier species under the particular local conditions where the disease occurs, such as the effect of temperature, humidity, and season upon life cycle changes and general activity, the maximum longevity of individuals, the possible distances which individual carriers may travel, and the complete list of food plants and the plants preferred by each species under various conditions of season and locality with especial reference to wild mosaic hosts. The importance of these points in relation to the inception and severity of mosaic epiphytotics cannot be overemphasized.

Carsner has suggested the term, "viriferous," to characterize the virus-bearing individuals among the insect population. Eventually we should know the histology and physiology of viriferous as compared with non-infective individuals of the carrier species. Does the insect function as an alternate host for the pathogene? Is the viriferous insect diseased?

A more intimate and fundamental understanding of the relation of carriers to the plant tissue and to symptoms produced is essential. The type of tissue punctured or injured and the constancy of feeding or ovipositing habits are important points. Why are aphids the surest means of securing inoculation with certain mosaics? Is it because they habitually penetrate a highly susceptible tissue such as the phloem?

The fact that in Europe the term, phytopathologist, is applied to both pathologists and entomologists bespeaks a point of view based primarily upon host injury and host reaction rather than the classification of the causal factor concerned. Such a point of view is much to be desired. Similar symptoms may be brought about by different causes. The work of Ball (6) and of Fenton (11) has clearly demonstrated the cause of hopperburn of potatoes and undoubtedly there is much to be learned about similar troubles in other hosts.

With insects as well as parasitic microorganisms the exact cause of host injury should be ascertained and proved somewhat in accordance with Koch's rules of proof. Smith (32) in England recently reported on his studies of the injury produced by a certain plant bug on apples. He recognized that the lesions might be due to laceration alone, to some toxic secretion of the insect, or to a transmissible parasitic organism and by inoculation and cultural tests he proved that the lesion was the result of a toxic salivary secretion. Recent work by Fenton and Ressler (12) on artificial production of potato tipburn with an emulsion of crushed adult leafhoppers also is illustrative of the type of work desired.

The possibility that certain strains or varieties of the host plant may prove somewhat resistant or distasteful to the particular insect carriers involved is indicated by Smith's observations (33, p. 154) on spinach mosaic in which he found the varieties Manchuria and Virginia less subject to aphis infestation than the Savoy variety.

The third class of problems are those to be solved preferably by some form of collaboration between entomologists and pathologists. A number of these problems have been outlined by Rand and Pierce (27, p. 220).

The determination of the particular species of insects involved in the transmission of each mosaic disease is essential. This necessitates actual transmission under controlled conditions and applies not only to the cultivated crops but the wild host plants as well. The relation of season and geographical location to the carrier species involved may be important. Particular attention should be given to the insects common to both cultivated and wild host plants, especially those present early in the growing season. Much remains to be determined about the natural transmission of many mosaic diseases such as bean mosaic, tomato mosaic, soybean mosaic, clover mosaic, potato leaf-roll, peach yellows, and pecan rosette. With the mosaic disease of potato the possibility of transmission by underground agencies is suggested by Quanjer's results (24), while Schultz and Folsom (30) have found no evidence of such a phenomenon. What is the fundamental difference between beet curly-top which is successfully transmitted only by the one species of leafhopper and such virus diseases as cucumber mosaic which may be transmitted in several ways? The relationship of the beet curly-top of the west to somewhat similar beet diseases reported from other parts of the country is unknown as yet.

Once the agency of a particular species of carrier insect is established for the disease under investigation, many questions remain to be answered. Work of the character of that done by Ball (5) on beet curly-top, and by McClintock and Smith (22) on spinach mosaic illustrates the type of investigation necessary to answer some of these questions.

How long a period of feeding upon a diseased plant is necessary for the insect to become viriferous? Is there a necessary incubation period within the insect's body?

How long must a viriferous insect feed upon a healthy plant to cause infection? What is the minimum number of individuals that may cause infection? In some cases, one aphis has been found sufficient. What is the relation of this number to the incubation period of the disease in the plant?

How long, after feeding on a diseased plant, does an individual remain viriferous? This is important in connection with the perpetuation of the virus over winter or during the period when the crop is not being grown. Does the condition persist through metamorphosis? In what stages of its life cycle is the insect a carrier?

Is the viriferous condition or infective capacity transmitted to the offspring? Through how many generations may this occur? McClintock and Smith (22) found that one of the aphid species which transmit spinach mosaic retained its infective ability through four generations on lettuce.

Is infection caused by the bite or feeding puncture or by oviposition? What is the localization of the virus on or in the insect's body? Is it external as on the feet or mouth parts or is it in the saliva or alimentary canal contents? Petri's work (23) on the persistence of the olive-knot bacteria in the fourth gastric pouch of the olive fly and the work of Rand and Cash (26) on the persistence of the cucurbit wilt bacteria in the alimentary tract of the striped beetle are illustrative of the type of information desired. In the terminology used by Rand and Pierce (27), is the transmission mechanical or biological?

Why do various species differ in their transmitting ability? Is this correlated with feeding habit and type of tissue punctured or with inability of the virus to endure conditions in or on the insect?

For each mosaic disease such investigation may lead up to control by some such means as:

1. Use of varieties or strains resistant to the virus or to the insect carriers.
2. Adequate control of the insect carriers and other agencies of dissemination.
3. Elimination of original sources of infection by (a) use of mosaic-free seed, vegetative propagation parts, or transplants and (b) eradication of volunteer plants and wild hosts, especially perennial weed hosts, in and near fields, plant-beds, and hothouses and maintenance of an isolation zone of a width to be determined by the distance traversed by the insect carriers.

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THE COOPERATIVE POTATO SPRAYING PROJECT: REPORT FOR 1921

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With Notes by Other Workers

This brief report, to supplement the data given in *Phytopath.* **11**, pp. 178-193 is made to bring the results of potato spraying and dusting experiments down to date. It is hoped that these experiments may be continued in the various regions where work is still needed.

Manitoba.—Preliminary tests were made by G. R. Bisby. Late blight has never been recorded in Manitoba, and early blight and tipburn (hopperburn) are not ordinarily serious. Spray and dust were applied in 1921 to a field of Bovee (Beauty of Hebron) potatoes at Winnipeg. The soil was not very good, and somewhat poorer toward one side; however, since the plots consisted of 4 rows sprayed or dusted alternated with 4 check rows, this source of error is compensated. A 5–5–50 Bordeaux was used, applied with a traction sprayer. Since the sprayer had but one nozzle per row, each plot was sprayed twice over at each application, the machine travelling in opposite directions. Three applications of spray were made July 16, 25, and August 4. Sander's copper lime dust was applied with a hand duster to the dust plots July 18, 27, and August 8. The sprayed plots were noticeably different during the summer, and remained green about 2 weeks longer than the check plots. No difference could be noted between dust and check plots. The potato beetle had been controlled on all plots with poison before spraying and dusting began. Some early blight and tipburn occurred, being worse on plots not sprayed. Yields were taken from the 2 middle rows of each plot.

TABLE 1

Yields in Manitoba in 1921

Treatment	Rows No.	Ave. yield per acre bu.
Sprayed	2, 3	178.2
Check	6, 7	127.9
Sprayed	10, 11	170.5
Check	14, 15	152.1
Sprayed	18, 19	173.2
Check	22, 23	142.1
Dusted	26, 27	149.8
Check	30, 31	123.6
Dusted	34, 35	113.7
Check	38, 39	97.2
Dusted	42, 43	92.9
Check	46, 47	89.1

[1] Coöperative project of the Advisory Board of American Plant Pathologists.

We may summarize table 1 as follows:

Average yield of 3 sprayed plots	174.0 bu. per acre
Average yield of 3 adjacent checks	140.7 " " "
Average increase from spraying	33.3 " " "
Average yield of 3 dusted plots	118.8 " " "
Average yield of 4 adjacent checks	113.0 " " "
Average increase from dusting	5.8 " " "

These results indicate that spraying pays in Manitoba.

Ohio.—E. E. Clayton carried out an extensive series of coöperative experiments on potato spraying and dusting in Ohio during 1921. Forty-four spraying tests were made, principally on areas of 1 acre or one-half acre in fields in Cuyahoga and Lake Counties.

The Rural New Yorker variety was grown in most cases, although several other varieties were tested. Most of these plots were sprayed 3, and 5 or 6 times, and 5-5-50 Bordeaux mixture was used. Various methods of application were tried. Most of the potato fields were planted June 15 to 20, and the spray was applied at about two week intervals, beginning usually early in July. Of these 44 spray tests, increases in yield were obtained in 41 cases and in only 3 cases were slight decreases found on sprayed areas. The data obtained from the 44 plots may be summarized as follows: An average of 32.5 bu. per acre increase was obtained from all sprayed plots. This is an average of 29.5 per cent increase over the unsprayed plots. The average cost was $10.27 per acre for spraying, and the average net profit from spraying during 1921 is figured at $42.65 per acre. The more important results are summarized as follows:

No. of nozzles[1]	Pressure	Increase in yield per acre
2 (5 tests)	75 lbs. (traction)	16 bu.
3 (16 tests)	75 lbs. (traction)	27 "
3 (23 tests)	200 lbs. (power)	39 "

Relation of number of applications of spray to yield and net profit in Ohio

No. sprays	Increase in yield per A.	Net profit per A. from spraying[2]
Traction sprayer		
3 (11 tests)	18.7 bu.	$22.42
5 or 6 (10 tests)	36.4 "	$36.80
Power sprayer		
3 (8 tests)	30.7 bu.	$42.21
5 (11 tests)	44.4 "	$61.30

The results from these spraying tests indicate a greater or lesser degree of control of hopperburn (tipburn), which was the major leaf disease in Ohio in 1921. Late blight was absent.

The most efficient spraying with Bordeaux 5-5-50, using 3 nozzles to the row, 200 lb. pressure and 5 applications, gave perfect control of tipburn from the point of view of the practical grower, and marked increase in yield.

Mr. Clayton also tested the complete potato dust as prepared by the Niagra Sprayer Co., and applied with a Niagra power potato duster. The results obtained on fields near Madison, Lake County, Ohio, are given in table 2.

[1] A number of men who sprayed with one nozzle to the row and 75 lbs. pressure reported no increase in yield.

[2] Computed from figures supplied by the growers.

TABLE 2

Results of dusting potatoes in Ohio in 1921.

Coöperator*	Variety	Date planted	Dates dusted	Area dusted	Yield per acre Dusted	Yield per acre Check	Increase	
				Acres	Bu.	Bu.	Bu.	Per cent
Mr. Benjamin	Wellington	June 1	July 7, 21 Aug. 5, 19 Sep. 3, 7	½	111.6	106.2	+5.4	+5.1
Mr. Kelen	Wellington	June 10	July 21 Aug. 5 Sep. 3	½	49.2	40.4	+8.8	+21.8
Mr. Faust	Holloway	June 1	July 7, 21 Aug. 19	½	70.0	72.6	—2.6	—3.6
Mr. van Gulick	Unknown	June 1	July 7, 21 Aug. 5, 19 Sep. 3, 7	½	85.8	71.4	+14.4	+20.2

* Three other coöperators reported no increase in yield from dusting but accurate yield data were not obtained.

New Jersey.—W. H. Martin obtained the following results in 1921:

1. Salem Co. A level field of Irish Cobblers on sassafras to sandy loam soil, fertilized with 2,000 lbs. 4-8-7 fertilizer per acre, was sprayed with home-made 5-5-50 Bordeaux mixture, except the check plots, which received only arsenate of lead. The Bordeaux was applied with a traction sprayer, three nozzles per row, 175 lbs. pressure, and 100 gallons per acre were applied. The first application of Bordeaux was made when the plants were seven inches high. No late blight, and only a trace of early blight, was present. Tip-burn was abundant. The sprayed plots remained green longer than the checks, the plots receiving 4 applications remaining green longer than those sprayed 3 times. Plots dug August 26, 1921; yield as follows:

Treatment	Yield per acre, bu.	Average
Check, (plots 1, 4, 7, 10)	150.8, 155.7, 157.4, 129.5 resp.	148.3
Bordeaux, June 13, 20, July 1, 8, (plots 2, 5, 8)	227.8, 239.3, 221.3 resp.	229.5
Bordeaux, June 13, 20, July 1, (plots 3, 6, 9)	214.2, 213.5, 178.1 resp.	201.9

2. Cumberland Co. Irish Cobblers were planted on sassafras loam, and fertilized with 1800 lbs. 4-8-7 fertilizer per acre. The last four plots were on an area somewhat lower than the remainder of the field. Bordeaux was used as above, except that the dates were different. Early season sprayings were May 26, June 1 and 13. Late season applications June 20 and 29; all season spraying included all five dates mentioned. On June 29 flea beetles were numerous on the check plots (arsenate of lead only applied) and on plots receiving early applications of Bordeaux; very few on plots which had the late applications. No early blight by June 29, but some leaves yellow from dry weather. Plots dug August 10; yield:

Treatment	Yield per acre, bu.	Average
Check, (plots 1, 4, 7, 11, 14)	90.2 109.6 128.0 131.6 134.5 resp.	118.8
All season, (plots 2, 6, 10)	116.8, 127.9, 144.3 resp.	129.7
Early, (plots 3, 8, 12)	120.8, 125.1, 152.8 resp.	132.9
Late, (plots 5, 9, 13)	120.3, 136.1, 135.8 resp.	130.7

On the above field a test of 20–80 copper lime dust was made. The dust was applied May 26, June 13, 20, and 29 by means of a power duster. The dust did not afford much protection from flea-beetles and on June 29 little difference between check and dust plots could be noticed. The dusted area yielded at the rate of 120.7 bu. per acre, in contrast to 118.8 bu. on the check plot.

3. Salem Co. Irish Cobblers planted July 25 as a second crop for seed purposes on a level field of sassafras loam. The spray plots were sprayed with home-made 5-5-50 Bordeaux with a traction four-row sprayer with three nozzles per row. Dust plots received, in one series, 20–80, and in another 15–85 copper lime dust applied with a hand duster, and the plants were thoroughly covered. Check plots were not sprayed at all, since insects were not present. Dust and spray applied September 1, 10, 20, 27, October 5, 14. Plots dug October 29.

Results as follows:

Treatment	Per cent of leaves dead			Yield per acre
	Oct. 5	Oct. 14	Oct. 21	bu.
Check	61.2	91.1	98.0	125.0
Bordeaux	1.3	15.3	55.0	163.5
20-80 dust	14.0	43.3	88.0	144.1
15-85 dust	12.8	46.6	92.0	139.4

The check plots suffered considerably from early blight and tipburn. The dusted plots were affected to a lesser extent by these diseases, and the Bordeaux plots but little.

4. Salem Co. Late crop Cobblers. The following tests were made by growers who formed a "spray ring." A traction sprayer which developed 175–200 lbs. pressure was used, and 5-5-50 Bordeaux was applied at the rate of 100 gallons per acre, at a cost of $2.06 per acre per application. Early blight and tipburn were the only diseases present. The yields in bu. per acre were as follows:

Test I. Sprayed 4 times, 160.1 bu.; check, 119.1 bu.

Test II. Sprayed 4 times, 213.5 bu.; sprayed 2 times, 198.6 bu. Check, 161.0 bu.

Test III. Sprayed 3 times, 213.4 bu.; check, 162.7 bu.

These results supplement previous data (see also N. J. Rept. **1920**: 577–587, 1921 and N. J. Circ. 122) and indicate that spraying Cobblers in New Jersey will result in increased yield even in the absence of late blight. Fair results were obtained from copper-lime dust on the late crop, in spite of the dry weather, but during 1921 dusting did not give as good results as Bordeaux.

Missouri.—J. T. Rosa, Jr., reports tests upon Early Ohio potatoes from northern Michigan which were planted at Columbia, Mo., March 17, 1921, and given 4 applications of 4–4–50 Bordeaux during May and June, both with and without lead arsenate and nicotine sulfate. The sprayed plants remained green about 3 weeks longer, and when dug August 28 yielded 34.2 per cent more than the checks. However, the tubers from the sprayed plots bore so many knobby second growths that the actual quantity of marketable potatoes was less than that obtained in the check plots, which bore few secondary growths. The Early Ohio variety has been found previously to be more subject to second growths than other early varieties grown at Columbia. Perhaps other varieties, such as Irish Cobblers, would not react in this manner. The weather conditions during 1921 were probably conducive to secondary growth of the tubers, since short wet periods alternated with longer dry, hot ones. These conditions were particularly apparent the latter part of the season when only the sprayed plants were alive. Knobby tubers should not necessarily be less valuable than uniform tubers for seed purposes. Tests of soil moisture and temperature relations, and of the state of dormancy in tubers whose growth is checked by weather conditions, need to be made.

Leaf hoppers became abundant during the latter half of the growing season on the above plots. Very little early blight and no late blight occurred. Tipburn was serious.

Pyrox did not keep the plants green quite as long as Bordeaux, but the yield was increased just as much over unsprayed plots as was the case with Bordeaux.

Kansas.—E. A. Stokdyk, working in coöperation with L. E. Melchers, submits the following data obtained in coöperative potato spraying tests with M. R. Kelsey, Topeka, Kansas, in 1921. The plots were one acre in size. Home made Bordeaux mixture with poison was used. A power sprayer, equipped with two nozzles to the row and spraying ten rows at a time at a pressure of 150 to 175 lbs., was used. Approxi-

mately 100 gallons were applied per acre. Check plots were sprayed with poison only. Plots sprayed 4 times had applications on May 23, June 3, 9, and 21. Plots sprayed 3 times had the May 23 spray omitted. Fields planted about March 30, and dug July 15 to August 15. Leaf hoppers present in the latter part of the season. Tip-burn and early blight about an average for Kansas, and as bad as or worse than in previous spraying tests. Late Blight does not occur in Kansas. The vines sprayed with Bordeaux remained green longer than the unsprayed ones.

TABLE 3

Results of spraying Early Ohios in Kansas in 1921

Spray applied	No. applications	Yields per acre, bu.	Cal. increase[1] per acre, bu.
Check	–	122.58	
Bor. 3–4–50	4	158.83	27.6
Check	–	139.88	
Bor. 3–4–50	3	191.80	43.7
Check	–	156.58	
Bor. 4–5–50	4	179.58	22.2
Check	–	158.25	
Bor. 4–5–50	3	160.00[2]	5.9
Check	–	150.00[2]	
Bor. 4–8–50	4	155.90[2]	6.5 loss
Check	–	174.81[2]	
Bor. 4–8–50	3	158.50[2]	0.65
Check	–	140.90[2]	

TABLE 4

Results of spraying Irish Cobblers in Kansas in 1921

Spray applied	No. applications	Yields per acre, bu.	Cal. increase per acre, bu.
Bor. 3–4–50	4	310.4	20.7
Check	–	289.7	
Bor. 3–4–50	3	310.9	24.6
Check	–	282.9	
Bor. 4–5–50	4	340.9	50.0
Check	–	299.0	
Bor. 4–5–50	3	279.1	5.4 loss
Check	–	270.0	
Bor. 4–8–50	4	285.5	34.2
Check	–	232.7	
Bor. 4–8–50	3	231.8	6.5
Check	–	218.0	

[1] Increase obtained by averaging the yield of two adjacent check rows, and subtracting the result from the yield of the sprayed row.

[2] Heavy rains had produced some irregular areas in these plots.

These results show an increase of 15.7 bu. per acre, or 10.5 per cent, from spraying Early Ohios, and an average of 21.8 bu. per acre, or 8.2 per cent, increase from spraying Irish Cobblers. Although these are not large increases, they indicate better results from Bordeaux under 1921 conditions than were obtained in the three previous seasons. The results up to date seem to indicate that with the methods used Bordeaux sprays for the potato crop in Kansas are of questionable value.

Eastern Canada.—P. A. Murphy gives (Canada Dept. Agr. Div. Bot. Bull. 44, 1921) valuable data on spraying in eastern Canada. The best results in fields were obtained from high pressure and three nozzles per row, although on small plots even better blight control can be obtained with hand sprayers. Bordeaux mixture was found to be better than Burgundy. Spraying before rains gave better results than spraying after rains. Many other data are given. The use of fungicides on potatoes in eastern Canada is rendered imperative by the prevalence of Phytophthora. An average of 130.5 bu. per acre yearly increase in yield of marketable potatoes was obtained from spraying with Bordeaux. Imperfect spraying, by keeping the vines green but not preventing development of Phytophthora, may result in more tuber rot than occurs on tubers from unsprayed fields.

G. E. Sanders finds that white arsenic may be combined with Bordeaux mixture and applied without injury to plants. (Agr. Gaz. Canada **7,** No. 1, 1920; Proc. Ent. Soc. Nova Scotia **6;** 8. 1921). He gives reports on dusting, but not specifically as applied to potatoes (Sci. Agr., Canada, Vol. **2,** 1921; Ann. Rep. Fruit Growers' Assn. Nova Scotia, **1921:** 66–92.)

Pennsylvania.—E. L. Nixon obtained in coöperative tests in 1921 even better results from the use of Bordeaux than those previously reported for Pennsylvania. Ten thousand one hundred and forty acres in 57 counties were included in spraying tests. An average increase of 74.3 bu. or 46.7 per cent was secured in the 402 demonstrations. Outfits yielding a minimum pressure of 200 lbs. were used in all cases. These results were obtained in a year with less late blight than occurred during 1918, 1919, or 1920. The spraying served to keep the plants alive over the extended drought which was fatal in many fields to the unsprayed plants.

West Virginia.—N. J. Giddings reports the following for 1921: At Wheeling, Irish Cobbler sprayed May 27, June 6, 20, and 30 with 5–5–50 Bordeaux mixture gave a 25 per cent increase in yield over the checks using hand sprayers. The plants were practically free from all leaf diseases except tipburn.

At Parkesburg, late potatoes (Carman) sprayed with hand outfit June 12, 16, and 27 gave a 20 per cent increase. Early potatoes sprayed May 21, June 2, 16, and 27 gave no increases. Tip burn was serious in both cases.

At Fairmount, early potatoes sprayed with hand outfits May 14, 26 and June 4, 17 and July 1 gave a 33.3 per cent increase.

At Davis three applications of spray using a power sprayer equipped with 3 nozzles to the row gave an average increase of 33.5 per cent in yield. A very little late blight was present at Davis.

Kentucky.—W. D. Valleau, Mr. Gardner and A. J. Olney report increases in yield and reduction in leaf hopper injury from the application of Bordeaux in 1921.

Indiana.—H. S. Jackson reports no authentic record of late blight in Indiana. Early blight is worst in the southern half of the state. Tipburn is very serious. Many commercial growers spray 3 to 5 times with 4–4–50 Bordeaux, which seems to be warranted by the partial control of tipburn secured.

British Columbia.—J. W. Eastham reports that spraying is not common over most of British Columbia because the Colorado beetle is absent, and late blight is absent over much of the province. Early blight may be destructive. An experiment at Sardis in 1918 indicated good results from Bordeaux against late blight.

Arizona.—J. G. Brown reports that Bordeaux checked the early blight attack in 1921 in Arizona. This disease spreads rapidly in Arizona during rainy periods unless the plants are sprayed.

H. W. Barre (*South Carolina*), J. G. Leach (*Minnesota*), J. A. Elliott (*Arkansas*) and M. B. McKay (*Oregon*) report no further data, nor have results for 1921 been received or noted from other regions not mentioned in this summary. Data from *North Dakota* by W. G. Colley and Dr. Weniger uncertain because of unfavorable weather.

SUMMARY

From the results obtained in 1921, it would seem that Ohio and Manitoba may be added as regions where the use of Bordeaux for potatoes is profitable. Supplementary data from New Jersey, West Virginia, Pennsylvania, certain other areas, and published results for Canada indicate further the value of spraying. Some further suggestions as to procedure, etc., may be gathered from the 1921 results. In the states of Kansas and Missouri, the value of Bordeaux is questionable.

During 1921 dusting trials on potatoes in New Jersey, Ohio and Manitoba gave results inferior to those obtained in spraying tests. This inferiority of dust in 1921 may perhaps be explained in part by the dry season and the absence of late blight in the areas where dust was tested.

APPENDIX

REPORT OF THE FOURTH ANNUAL MEETING OF THE SOUTHERN DIVISION OF THE AMERICAN PHYTOPATHOLOGICAL SOCIETY, AT LANTA, GEORGIA, FEB. 20-22, IN CONNECTION WITH THE GENERAL MEETING OF THE ASSOCIATION OF SOUTHERN AGRICULTURAL WORKERS.

The meeting of the Southern Section of the American Phytopathological Society held at Atlanta, Georgia, in conjunction with the general meeting of the Southern Agricultural Workers was poorly attended, although fairly well represented by workers from the Southern States which are near to Georgia. It is unfortunate that such meetings are not better attended because problems of immediate concern are usually taken up which should interest southern plant pathologists. The meager attendance was probably due to the fact that many of the workers attended the general meeting at Toronto and felt that they could not attend both.

The program was arranged in a manner more or less similar to that carried out last year, that is, part of the time was given to a joint session with the Horticultural Society and the other part to the meeting of phytopathologists alone. Considerable prominence was given to a discussion of the sweet potato and its diseases which was really in the nature of a symposium and which consisted in reviewing work previously done. The object of this symposium was primarily to interest the horticulturists and have them present their side which deals with the cultural end of this important southern crop. As a criticism, it might be said that few original papers were presented which might, perhaps, indicate a lack of interest. In the future, it is planned to make these meetings more interesting and have more papers presented on some definite problem of plant pathology which concerns the Southern States.

The following officers were elected for the ensuing year:

Chairman—Professor H. W. Barre, Director of South Carolina Experiment Station.

Vice Chairman—Professor S. H. Essery, Mycologist and Plant Breeder, University of Tennessee, Knoxville, Tennessee.

Secretary—Dr. J. J. Taubenhaus, Chief, Division of Plant Pathology and Physiology, Texas Agricultural Experiment Station, College Station, Texas.

Representative to the Council of American Phytopathology—Dr. L. R. Hesler, Botanist and Plant Pathologist, University of Tennessee, Knoxville, Tennessee.

Upon motion it was agreed that the Association of Southern Agricultural Workers be asked to appoint a committee to work on a coöperative project on root knot, this being an extremely serious disease in all the Southern States, the committee to consist of a plant pathologist, an entomologist, a horticulturist, and an agronomist. In the absence of Dr. Eliot, Professor H. W. Barre acted as chairman.

Respectfully submitted,

J. J. TAUBENHAUS, Secretary.

ABSTRACTS OF PAPERS READ

Recent studies of Texas root rot of cotton. J. J. TAUBENHAUS.

Studies were reported on the life history of *Ozonium omnivorum* as it affects the cotton. It was found that the fungus does not live over in the soil, nor on decaying organic matter, but that it requires a living root on which to pass the winter. Roots of cotton plants, wild morning glory, castor bean, okra, pepper, and probably many others afford a root host on which the Ozonium winters over. Successful inoculations were also reported for the first time, using *Ozonium omnivorum* and successfully infecting healthy cotton plants. The method employed was somewhat different from the usual way. It was also reported that spores corresponding to the Phymatotrichum stage which Duggar described some eight years ago were found on pure cultures, using sterilized soil as a medium. Extended studies covering a period of seven years were made in which control methods are practically developed. The results of this work will be published in a station bulletin shortly.

The Ascochyta blight of cotton. JOHN A. ELLIOTT.

The Ascochyta blight of cotton, attributed to *A. gossypii* Sydow, was locally severe in west central Arkansas in June, 1920. Investigation showed that a serious epidemic of the same disease had occurred in the same region in August, 1915. Both outbreaks took place during periods of excessive and continued rainfall. A less serious outbreak occurred in June and July of 1921, under similar conditions. From circumstantial evidence, it is thought that the disease is at present of local occurrence. Potentially, it is a disease of great importance, a period of continued wet weather being the only condition required for the complete destruction of the cotton crop when the disease is present. Dry weather checks the advance of the disease.

Corn mosaic in Arkansas. H. R. ROSEN.

Corn mosaic is reported as having been collected in Mississippi County, Arkansas, in 1921.

The control of Root-Knot. A progress report. J. A. MCCLINTOCK.

Experiments conducted by the writer at the Georgia Experiment Station during the past three years have shown the possibilities of root-knot nematode control through the use of resistant plants. Various plants have proven resistant to the root-knot nematode, the most recent addition to the list being a seedling peach. Seed of this peach have been planted to determine whether the factor of resistance is seed transmitted in the case of this peach. As data are collected a report will be made relative to this point, and in the meantime workers should watch for resistant individuals among various plants which are infested by root-knot nematodes.

Dusting vs. spraying for the control of the curculio, brown rot and scab of peaches. OLIVER I. SNAPP.

Data from two years' work in Mississippi and one year's work in Georgia show the liquid spray to be somewhat superior to the dust for the control of the curculio under heavy infestations, but for brown rot and scab control the two methods of pest control gave about equal results. The 80–5–15 dust formula gave practically as effective control of circulio, brown rot and scab yearly as the 80–10–10 or other dust formulas

containing more arsenate of lead. An application of arsenate of lead when seventy-five per cent of the petals were off and another four weeks before the fruit is due to ripen in addition to the treatments when the calyces were shedding and again in two weeks is strongly advised, especially in latitudes where two generations of the curculio occur.

Field and storage diseases of the sweet potato and their control. L. L. HARTER.

The diseases of the sweet potato may be roughly divided into three groups, as follows: (1) diseases of the leaves, (2) diseases of the root and stem, and (3) storage rots.

The diseases of the first group require no remedial measures. To control diseases of the second group care should be given to seed selection, seed disinfection, care in the preparation of the hot bed, and crop rotation. The seed potatoes should be selected in the fall at digging time and again in the spring just before bedding. A new hot bed should be made each year. The seed potatoes should be disinfected for from 5 to 10 minutes in a solution of mercuric chloride made by dissolving 1 ounce of mercuric chloride in 8 gallons of water.

To keep potatoes in storage they should be dug just preceding frost and handled carefully. The storage house should be kept dry and at a temperature of about 50 to 55° F.

Notes on the physiology of the sweet potato. WRIGHT A. GARDNER.

This paper consisted of a review of the literature of work on sweet potatoes, with special reference to transformations of carbohydrates.

Results of preliminary investigations were reported which indicate that there is little or no injury when tops of sweet potato plants are removed two weeks before digging; that topping and severing of roots results in considerable rotting; that cured sweet potatoes are not injured by the outdoor conditions which prevail when the temperature falls to 3.8° C during a frosty night; and that the expressed juice of sweet potatoes shows a depression of freezing point amounting to 1.28° C.

Fusaria of corn. C. D. SHERBAKOFF.

The author's recent studies of Fusaria associated with corn seed show that there are several different species of this genus more or less commonly isolated from the seed, some of the species resembling each other in their appearance on agars ordinarily used in a similar work. It is suggested that there might be a difference also in the pathogenicity of these Fusaria. Because of the great importance of corn rootrot in Tennessee, the local experiment station is starting this season certain experiments with corn to determine (1) the different Fusaria associated with corn seed, (2) the correlation between the results obtained from rag-doll and sand-box tests of the seed and rootrot in the field and (3) the effect of certain methods of seed treatment on corn rootrot. Other plant pathologists of the South are invited to coöperate in the work.

The less common spray materials. N. D. PEACOCK.

All new spray materials should prove themselves better than the standard materials before they will be accepted for general use. They should be compared with the standard materials in efficiency, cost, convenience and danger of injury.

Practically all of the proprietary fungicides have either copper or sulphur as a basis and are therefore directly comparable to either Bordeaux mixture or lime-sulphur.

Some of the newer much advertised spray materials are very promising and deserve consideration, others are of indifferent value and some perhaps are decidedly objectionable. Growers should use all of these materials experimentally (if at all) before adopting them for general use.

Three years sweet potato certification work in Arkansas. GEO. G. BECKER.

The sweet potato certification service which is being conducted by the Arkansas State Plant Board has been in operation for three years without modification and is doing every thing that was expected of it. Through sheer merit and consistent dependability Arkansas certified seed and slips will in time make it difficult to dispose of sweet potato seed and slips on any large commercial scale unless they are certified.

In addition to the present requirements for getting a sweet potato slip certificate we will this year require that the location of the slip bed be approved by an inspector of the board before seed can be bedded down for certified slips. Experience teaches us that purchasers of certified seed must be made to understand that certified seed is not immune to diseases. We accordingly supply all of our certificate holders with information to give to their customers and we find that they are glad to distribute this for their own protection. We are thoroughly convinced that no certification service can be conducted unless we have in our employ, or can work in close coöperation with a thoroughly competent Plant Pathologist.

"Mosaic" disease of corn in Arkansas. H. R. ROSEN.

'"Mosaic" disease of corn has been noted for two successive years in northeast Arkansas. Comparatively few plants were found attacked and of these only a small number were so seriously affected as to influence the production of normal ears. Badly diseased plants are very much stunted, due principally to a shortening of upper internodes, possess chlorotic spots and stripes in great profusion, and contain a compact group of shortened leaf-blades, presenting a rosette appearance, at the top of the plant. Such plants produce abortive ears only. Present observations indicate that under Arkansas conditions the disease is not as serious or as common as in the Hawaiian Islands.

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